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CONTENTS

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BREEDING RANGE AND POPULATION STUDIES OF COMMON SNIPE IN CALIFORNIA [1]

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Studies were conducted between 1978 and 1981 to determine the breeding range of Common Snipe, *Gallinago gallinago delicata,* in California. Methods of measuring population densities and monitoring population trends were also investigated. We estimate that approximately 38,000 ha of potential breeding habitat exists within the known breeding range in the state. Breeding grounds are used from late March through September. The peak of breeding and nesting activity occurs in May and June. Banding information indicates that snipe tend to return to the same breeding grounds. Breeding densities of 14.5 pairs per 100 ha were counted on the Deer Creek study area.

INTRODUCTION

Although Tuck (1972) and Sanderson (1977) provide extensive reports on the distribution and life history of Common Snipe in North America, no general assessment of breeding range and population status in California has appeared since Grinnell and Miller (1944). California supports both breeding populations and winter residents.

The objectives of this study were (i) to provide an up-to-date description of the distribution of snipe in California during the breeding period, (ii) to describe activities of the birds on the breeding grounds, and (iii) to describe and assess methods of measuring population densities and monitoring population trends.

STUDY AREAS

Two study areas were used to gather detailed information on breeding ground activities. The primary area was Deer Creek Meadows which is located in northeastern Tehama County at an elevation of 1300 m. The study area covered 25 ha in 1979 and was expanded to 88 ha in 1980. Habitats ranged from well drained grass uplands to constantly wet "bogs". Bogs and very wet zones which support short-beaked sedge, *Carex simulata*, and beaked sedge, *C. rostrata* were most important to snipe. Beaked sedge dominates areas too boggy for cattle to graze. Stands of lodgepole pine, *Pinus contorta murrayana*, are found in very wet areas of the meadow. Most of the trees are dead. Cottongrass, *Eriophorum* sp., and bogbean, *Menyanthes trifoliata*, which are characteristic of northern fen communities (Tuck 1972) are also found here. By early June the only areas providing good nesting cover were boggy areas and marshy sites within the timber stands.

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A secondary study area was Mountain Meadows in western Tehama County at an elevation of 1500 m (Figure 1). The habitat gradually shifts from sedge marsh to sedge meadow to upland. Sedge marsh and sedge meadow are important for snipe (Tuck 1972). The dominant sedge of the meadow is *Carex simulata* and the wetter areas near the lake are dominated by *C. nebraskensis*. Areas of northern mannagrass, *Glyceria borealis*, also occur in ditches and along the lake shore. Water levels at Mountain Meadows are highly variable in late spring when much of the area usually has dried out and is irrigated for cattle pasture.

FIGURE 1. Breeding range of Common Snipe in California.

METHODS AND MATERIALS

Early field work showed it was infeasible to locate and map all existing breeding habitat from the ground. Color infra-red film covering most of the snipe's breeding range in California was obtained from the U.S. Forest Services'

Remote Sensing Unit in San Francisco. Photographs were taken with a panoramic camera mounted in a U-2 high-altitude aircraft. Each frame covered a land area approximately 3.7 $\times$59.5 km. A color signature was developed for breeding habitat by studying known breeding grounds on the film. Individual frames were examined using this signature, together with field data, to locate known and potential breeding habitat. Areas were located and transferred to black and white ortho-photographic quads. Once the quad was completed, a planimeter was used to determine the acreage at each location.

Known habitat is defined as any area for which there are recent records of use by snipe during the breeding season. Potential habitat is defined as any location which has the same signature but has not been ground-checked to determine actual use by snipe.

The U.S. Fish and Wildlife Service system of classifying wetlands (Cowardin *et al.* 1979) was used to catagorize breeding habitat. The majority is Palustrine Emergent Wetland. This classification includes areas typically called marsh, meadow, fen, bog, slough, and prairie pothole.

Adult vocalizations and displays aided us in locating territories, nests, and young. Territorial displays observed included winnowing, arched-wing, and distraction displays. Most vocalizations were the scaipe note and yakking (Tuck 1972, Williamson 1950).

Breeding densities were determined by territory mapping. A taped recording of a snipes yakking call was played while walking transects through the area. As birds responded to the call their position was noted. If a bird flew to the location of the tape or performed overhead, the location was considered to be within the bird's territory. The location of the tape was considered to be beyond the snipe's territory if the bird responded but failed to fly to this location. The Deer Creek area was monitored in this manner during two breeding seasons.

Three-tier mist nets with 10 cm stretched mesh were used to capture snipe for banding and color marking. Various parts of the plumage were dyed with picric acid and/or Rhodamine B for future identification. Specific patterns were used to identify individual birds throughout the breeding season. U.S. Fish and Wildlife Service leg bands were placed on all birds.

Transects were walked on the Deer Creek study area following a period of intensive trapping and color marking. A Lincoln Index was used to calculate an estimated population.

A driving transect, based on one used by Tuck (1972) in Canada, was established on the Mountain Meadows study area to test its value for collecting breeding population data (Figure 2). The transect consisted of eight stops at 0.8 km intervals. The observer recorded the number of birds heard winnowing and/or yakking during a 2 min period at each stop. The route was run four times during each check. Counts were made at 1 h before sunrise, at sunrise, and 0.5 h before and after sunset. The number of birds heard at each stop was recorded. When possible, counts were made once a week from April through mid-July. Chi-square tests were used to detect differences in winnowing and yakking activity.

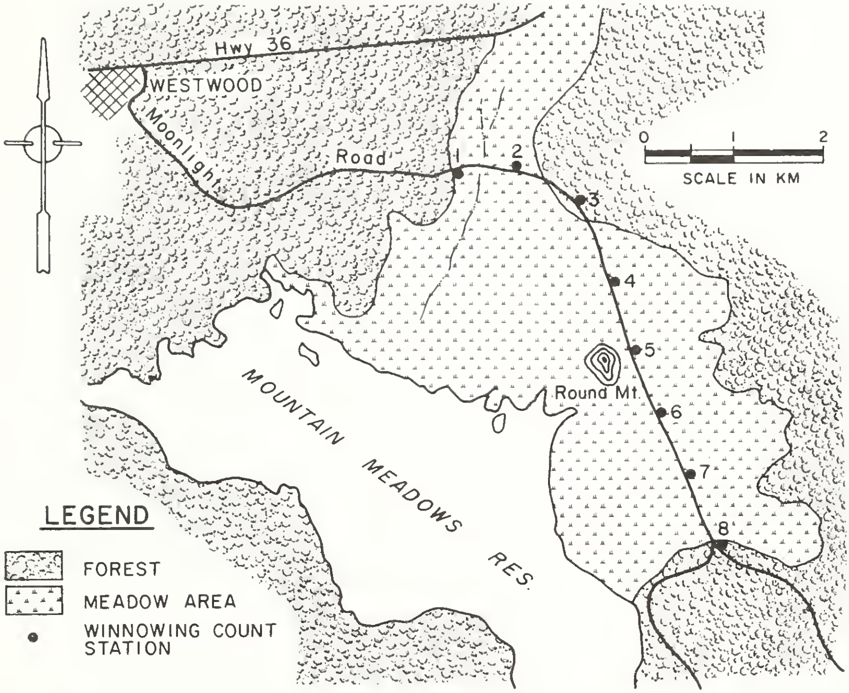

FIGURE 2. Winnowing count stations on Mountain Meadows study area.

RESULTS AND DISCUSSION

Breeding Grounds

Location

Most of California's breeding snipe nest in the northeastern part of the state. The western boundary of the breeding range closely follows the western edge of the Cascade Range from the Oregon border south to the Sierra Nevada. It continues along the Sierra crest to Lake Tahoe and south along the eastern edge of the sierra through Mono county. The northern and eastern boundaries are the state lines (Figure 1). This delineation differs somewhat from that described by Grinnell and Miller (1944), which may represent changes in breeding range or merely the location of sites not previously recorded. This study extends the breeding range to the west in several areas of the state to include Scott Valley in western Siskiyou County; areas around Whitmore and Oak Run in south central Shasta County; Browns Valley, central Yuba County; and several isolated locations east of Sheridan in northwestern Placer County.

Breeding habitat has been lost in most of Inyo County because of changes in agricultural practices caused by diversion of water for southern California. However, remnant breeding populations still exist; a clutch of eggs was collected

near Olancha in southern Inyo County in 1971 by the Western Foundation of Vertebrate Zoology (Kimball Garrett, pers. commun.). A juvenile and two adults were observed in May, 1983. Reports of isolated breeding activity in northwestern Los Angeles County and western San Bernardino County were found in the literature (Grinnell and Miller 1944). Most suitable habitats have been engulfed by urbanization. Infra-red film showed potential habitat near Lake Isabella, northeastern Kern County. Breeding activity was observed during a field check in May 1983. This finding leads us to believe that other areas may exist along the west slope of the Sierra.

Breeding habitats were generally found between elevations of 750 m and 1500 m. Isolated locations were recorded as low as 60 m to over 2000 m. Low elevation sites were located along the west slope of the Sierra Nevada outside the major breeding range. Successful nesting was documented at one isolated site in Yuba county at an elevation of approximately 150 m. Nesting also has been documented at higher elevations; 1900 m at Kyburz Flat, Sierra County, and 2000 m on Sagehen Creek, Nevada County (Vern Hawthorne, pers. commun.).

From the U-2 infra-red film we estimate there are 14,000 ha of known breeding habitat and 24,000 ha of potential breeding habitat within the breeding range (Figure 3). These totals could vary from year to year depending on rainfall and habitat conditions.

Period of Use

Snipe were first seen on the breeding grounds during the last half of March. The earliest sighting was March 15, 1978 at Deer Creek Meadows. By early April breeding activity was well underway throughout much of the range. Breeding activity continued through mid-July, 1980 when territorial displays ceased abruptly, coinciding with the hatch of late clutches and the onset of post-breeding molt by late nesting adults (Tuck 1972). Fall departures from the breeding grounds were not monitored. However, during the last week of August, 1980 an intensive banding and color marking effort was undertaken on Deer Creek Meadows. Subsequent flushing counts indicated a population of approximately 69 birds. By the last week in September only 15 birds were counted. No birds were located at either study area during the winter.

Wintering birds were found on a breeding area in Indian Valley, Plumas County. One bird banded at this site in September was collected there the following January, showing that some of the breeding population may not always migrate. A second bird banded at this site was reported shot the following April in Culiacan, Mexico.

A total of 115 snipe was banded on the two study areas. Nine were recaptured at these locations in subsequent years indicating they tend to return from wintering grounds to specific breeding grounds.

Population Densities

The best indicator of territory, nests, or the presence of young is the behavior of the adults. Vocalizations and displays were the key to determining breeding population densities on Deer Creek Meadows.

During the 1980 breeding period, 13 territories were located on the 88 ha study area (Figure 4). This would indicate a breeding density of 14.5 pairs per 100 ha. This exceeds densities given by Tuck (1972) of 5.5–13.2 for sedge bog and

3.5–7.7 for fen habitats in Canada. Our density figure represents the total number of breeding birds on the area for the entire season. Some of the late nesters were able to utilize habitat that had been defended by other snipe earlier in the year.

Nests were located in eight of the 13 territories. New nests were started almost every week with the onset of incubation ranging from May 1 through the end of June. Based on hatching dates at Deer Creek Meadows and the ages of nine flightless juveniles captured at Mountain Meadows, sixty percent of the nesting activity occurred in May.

The 25 ha area of lower Deer Creek Meadows counted in 1979 contained six pairs of snipe. The same area contained eight pairs in 1980. The 1979 density was 24 pairs per 100 ha and the 1980 density was 32 pairs per 100 ha. This area was the most heavily utilized portion of the meadow in both years because of the excellent nesting habitat and thus produced inflated densities when compared to the whole breeding ground.

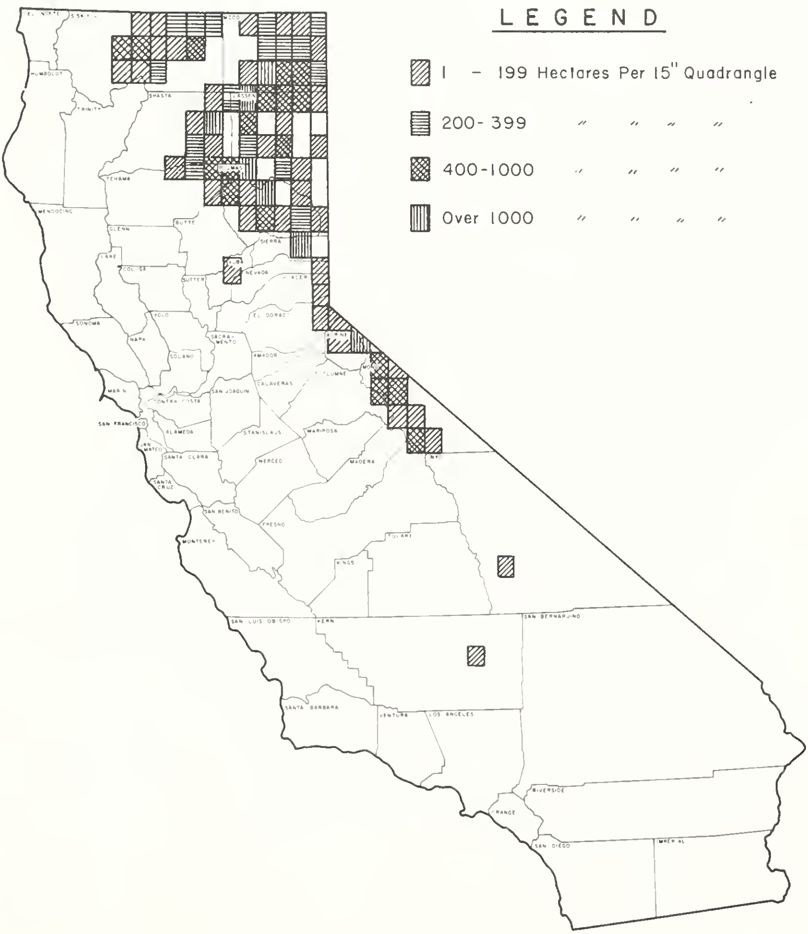

FIGURE 3. Breeding habitat acreage density by 15 minute quadrangles.

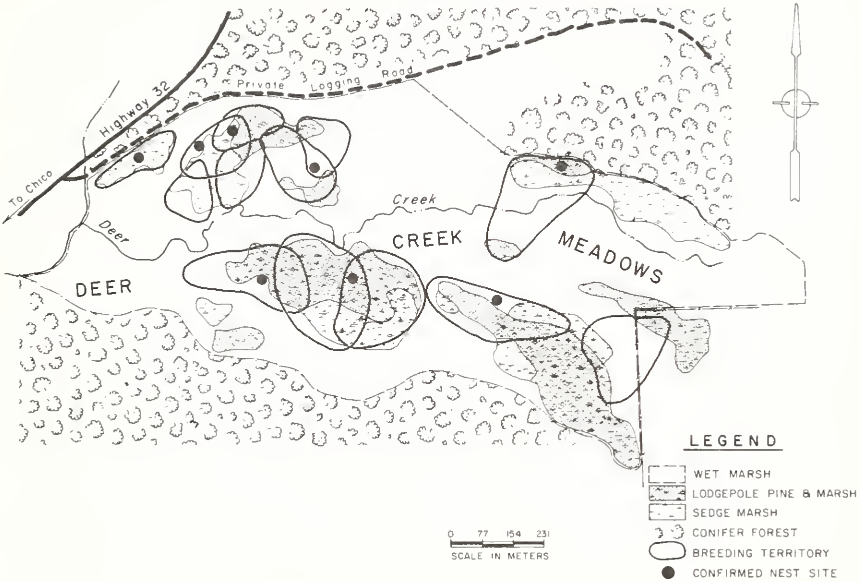

FIGURE 4. Locations of snipe breeding territories in Deer Creek Meadows, 1980.

Winnowing Index

Driving transects were run from April through mid-July. The first peak in winnowing activity occurred during the first week of April, probably indicating the arrival of females (Tuck 1972). Counts fluctuated up and down through April and May. A second peak occurred in June (Figure 5). This peak may result from the continuing territorial display by some adult males plus displays from yearlings that are just reaching breeding maturity.

Irrigated pasture creates new breeding habitat late in the season and attracts unpaired snipe to establish territories. This type of habitat is common throughout the breeding range and is generally used for summer grazing by cattle.

We found that winnowing counts at sunset were significantly higher than morning counts ($X^2 = 4.60$, $P < 0.05$). This agrees with Tucks (1972) findings and indicates this time period is best for conducting counts. Although the winnowing pattern through the breeding season was similar in 1979 and 1980 (Figure 5), the level of winnowing was significantly higher in 1980 ($X^2 = 13.79$, $P < 0.05$). This annual fluctuation has potential for use as a survey method to monitor breeding ground activity.

Winnowing is primarily a male sexual display to attract the female. Yakking is done by both sexes to declare a territory (Tuck 1972). Yakking counts were relatively constant during all count periods ($X^2 = 0.35$, $P > 0.05$). Daily observations for yakking and winnowing indicate lower variance in yakking counts throughout the day and during any count period except postsunrise. We believe that yakking counts may have value as a survey method to determine breeding pair densities. Further studies are needed to compare yakking counts to areas where territories have been mapped.

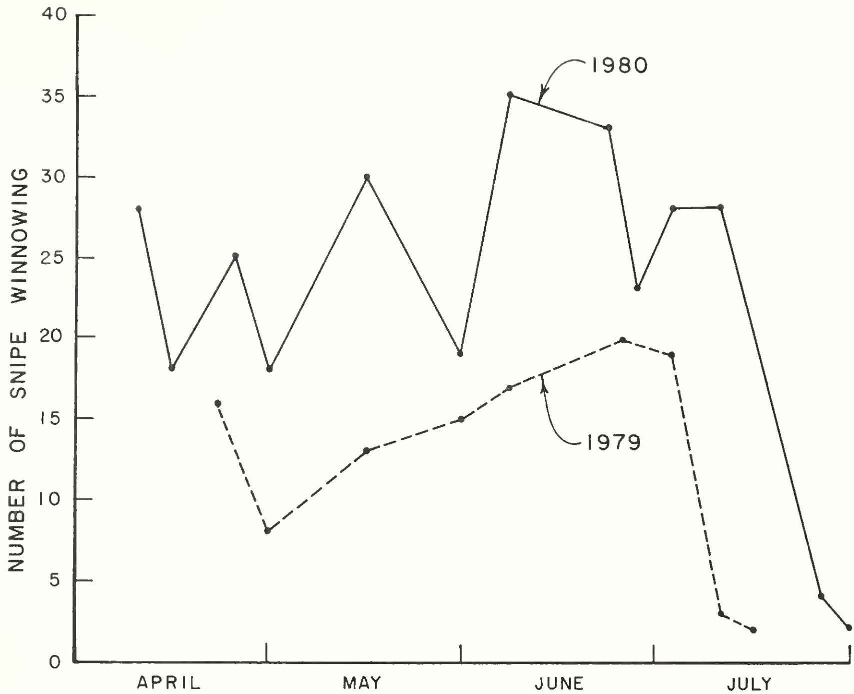

FIGURE 5. Post-sunset winnowing activity patterns on Mountain Meadows study area.

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We express our appreciation to J. Caylor and W. Salizar of the U.S. Forest Service for providing the color infra-red film and for training us in its use. We wish also to thank E. Cummings for his efforts in analyzing the statistical data and E. Ohara for preparing the figures.

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Calif. Fish and Game 71(2): 76–87 1985

GROWTH, FOOD, AND HABITAT OF AGE 0 SMALL-MOUTH BASS IN CLAIR ENGLE RESERVOIR, CALIFORNIA [1]

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A total of 342 age 0 smallmouth bass, *Micropterus dolomieui*, from Clair Engle Reservoir, Trinity County, were collected with seines from July through September 1979 as part of growth, diet, and habitat studies. Mean length in mid-September was 84 mm; a relatively low value. Protected habitat areas were favored during spring and early summer. Fish tended to move to more exposed habitats as they became larger and weather conditions moderated. Favored bottom substrates included shale, rocky-rubble, sand and gravel, and areas with stumps and submerged logs. No bass were collected in areas with exclusively mud bottoms. Aquatic dipterans (primarily chironomid larvae and pupae) dominated the age 0 bass diet.

INTRODUCTION

Clair Engle Reservoir, formed in 1960 by the closure of Trinity Dam, on the Trinity River, is part of the U.S. Bureau of Reclamation Central Valley Project in northern California. Soon after impoundment a fishery developed for largemouth bass, *Micropterus salmoides*, and smallmouth bass, *M. dolomieui*. Bass were introduced when old dredge ponds were flooded during reservoir filling, and both species established naturally reproducing populations. The smallmouth bass fishery is the larger, and fishing effort for this species has increased dramatically over the years. Other species contributing significantly to the fishery include brown trout, *Salmo trutta*, rainbow trout, *S. gairdneri*, and kokanee salmon, *Oncorhynchus nerka*.

As bass populations increased, a trophy smallmouth bass fishery developed. To prevent over-exploitation of the smallmouth bass population, the California Department of Fish and Game imposed a 30.5-cm minimum length limit in 1976. Although this size limit has been successful elsewhere for conserving smallmouth bass populations (Surber 1969), it is not clear that this regulation alone will be sufficient to maintain a quality fishery in Clair Engle Reservoir. Preliminary data indicated rapid growth of smallmouth bass in the reservoir (J. Thomas, unpubl. data), although Coleman (1978) found that the reservoir was cold and unproductive, with low standing crops of zooplankton. Knowledge of the food, growth, and habitat of age 0 smallmouth bass in this reservoir should enable the refinement of the management plan for the population.

STUDY AREA

Clair Engle Reservoir is about 40 km northwest of Redding, California, on the upper reaches of the Trinity River, at an elevation of 724 m above mean sea level. The reservoir has a maximum capacity of 3.1 billion m^3 of water; it is 30 km long and 0.8 to 3.2 km wide, with a shoreline of 240 km and a surface area of 66 km^2. The reservoir is 136 m deep at the dam and is deep throughout most

[1] Accepted for publication March 1984.

[2] Cooperating agencies are the Humboldt State University, the California Department of Fish and Game and the U.S. Fish and Wildlife Service.

of its length.

The reservoir is considered oligotrophic and is similar to other deep mountain lakes in California (Coleman 1978). It has seven major tributaries: Trinity River, East Fork Trinity River, Swift Creek, Feeney Creek, Papoose Creek, East Fork Stuart Fork, Stuart Fork. Most of the inflow is snowmelt from nearby mountains. The steep banks are devoid of aquatic plants and most trees were removed before the reservoir was filled.

METHODS

Nine stations were sampled with seines at 2-wk intervals during April–June 1979 and April–May 1980, and weekly during July–September 1979 (Figure 1). Stations were selected on the basis of preliminary seine surveys and the most productive seinable areas within different habitats were assigned station numbers. Stations were classified into three habitat "types", based on a visual description of the sampling areas. Habitat 1 (stations 2, 6 and 7) was characteristic of protected areas near major tributaries; habitat 2 (stations 4 and 5) was characeristic of sheltered, gently sloping littoral areas; and habitat 3 (stations 3, 8, and 9) was characteristic of unprotected steeply sloping littoral areas. Station 1 (a representative of habitat 3) was sampled only once in early July and was not included in the fish growth and food analyses by habitat type.

Stations associated with streams (habitat 1), were cooler than other areas and were protected from winds. Some macrophytes and flooded terrestrial vegetation were in the areas when water levels were high. The bottom substrate consisted of sandy-gravel, flooded weeds, dead small rooted shrubs, and a few submerged logs and rock piles. Turbidity was low during the sample period. The sheltered flat areas (habitat 2) were protected from heavy winds and waves, since they were in small bays with narrow outlet channels. Aquatic plants were scarce, and at high water levels little terrestrial vegetation was flooded. Tree stumps were the major cover. Bottom substrate ranged from a sandy-mud mixture to rocky rubble. Water in this area was moderately turbid even during fairly calm weather. The open water areas (habitat 3) were steeply sloped with shale, gravel, or rock shorelines and little vegetation. During windy periods the shoreline was subject to erosion by wave action, and nearshore turbidity was high.

Surface water temperature was taken with a pocket thermometer during each sampling period at the station where data collection began.

Age 0 smallmouth bass were collected with two seines, one 9.1 by 1.2 m with 3.2-mm mesh, and another 15.2 by 1.8 m, with 5.9-mm mesh (bar measure). Both seines were used during each sampling period. Fish were preserved in 10% buffered formalin and later measured fork length (FL), (to the nearest millimetre) and weighed (to the nearest gram) 30 s after they were blotted on clean filter paper. Mean lengths and weights of bass were compared by habitat and month using the Student-Newman-Keuls procedure (Sokal and Rohlf 1969). Total bass catch, by habitat and time, were compared using Friedman's test (Langly 1971).

We determined length-weight relation, $W = aL^{b}$, using the computer program "Growth" (Mawson and Reed 1969), as modified by Collins (1977), where: W = weight in grams, L = FL in millimeters, and a and b are constants. Fork length was converted to total length (TL) by the formula, TL = 1.04 *FL* (Fry and Watt 1957).

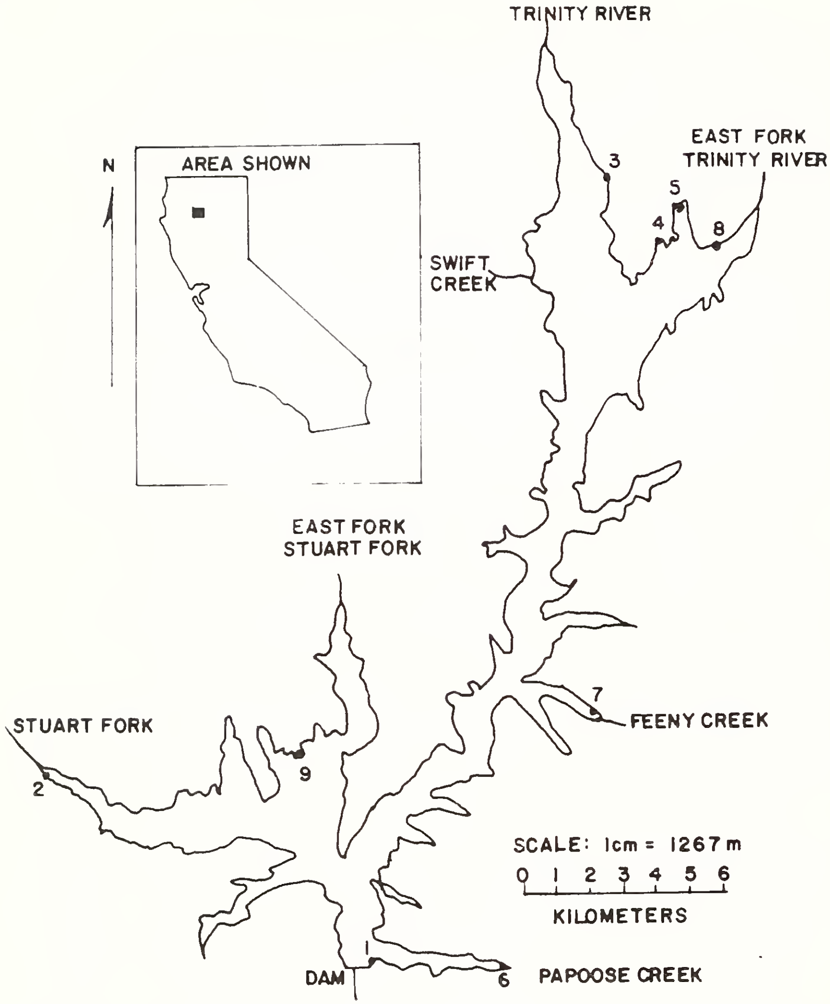

FIGURE 1. Clair Engle Reservoir California, showing sampling stations in three types of habitats: (1) protected areas near major tributaries (Stations 2, 6, and 7); (2) sheltered gently sloping littoral areas (Stations 4, and 5); and (3) unprotected steeply sloping littoral areas (Stations 1, 3, 8, and 9).

Stomach contents for each fish were examined microscopically and food items identified using keys published by Pennak (1953); Fernald and Shepard (1955); Usinger (1963); Edmondson (1966); Comstock (1972); Borr, Delong and Triplehorn (1976); and Leumkuhl (1979). Unidentified food material and empty stomachs were recorded.

Abundance of food items in each fish stomach was characterized by three methods: volumetric, numerical, and frequency of occurrence (Larimore 1957, Windell 1971, Clady 1974, George and Hadley 1979). Major food groups (those 0.05 ml or more in total volume and representing more than 0.1% by number)

were tabulated by habitat and time of collection. Volumes of benthic organisms, fish, and aquatic and terrestrial insects were measured by water displacement in a calibrated centrifuge tube. Volumes of zooplankton, ostracods, and amphipods were estimated by making several measurements for each species and computing an average volume per individual of a species, and then multiplying by the number of individuals of that species per stomach (Langdon 1979). Frequency of occurrence consisted of the number of stomachs containing food of a given group, expressed as a percentage of the total of 221 full stomachs that were examined (Windell and Bowen 1979).

Stomach contents from each fish also were evaluated by using the Index of Relative Importance (IRI: Pinkas, Oliphant, and Iverson 1971), for each food item: $IRI = (N + V)FO$, where N = percentage of total number, V = percentage of total volume, and FO = percentage frequency of occurrence.

RESULTS

Catch By Habitat

A total of 342 age 0 smallmouth bass were collected from all habitats (Table 1). Age 0 bass were caught only during July-September 1979. The catch decreased significantly from 208 in July to 30 fish in September $P<0.05$) but did not differ significantly by habitat type. Age 0 bass were caught throughout the reservoir in rocky-rubble areas and in areas with stumps and vegetation, but no bass were caught in areas with mud bottoms. Reservoir water level was maximum and stable from mid-May to mid-July and all stations were seinable. Water level dropped 9.5 m from mid-July through September and most stations were difficult to seine.

TABLE 1. Numbers of Young-of-the-Year Smallmouth Bass Collected in Different Habitats from Clair Engle Reservoir, California, Summer 1979.

Habitat	*July*	*August*	*September*
1 [a]	107	39	11
2 [b]	55	27	8
3 [c]	46	38	11
Total	208	104	30

[a] Protected areas near major tributaries.
[b] Sheltered, gently sloping littoral areas.
[c] Unprotected steeply sloping littoral areas.

Growth

Mean FL of age 0 smallmouth bass increased from 32 mm in early July to 84 mm by mid-September and mean weight from 0.6 g to 8.7 g (Figure 2). Age 0 bass from the three habitats averaged the same size in July (Table 2). Fish captured in habitat 1 during August were significantly smaller than fish from habitats 2 and 3 ($P<0.05$; mean 54.3 mm FL and 2.4 g versus 63.1 mm and 4.0 g). Fish captured in habitat 1 during September were significantly shorter than fish from habitats 2 and 3 ($P<0.05$; mean 72 mm versus 78.4 mm) but were significantly lighter only than fish from habitat 3 ($P<0.05$; mean 5.9 g versus 7.3 g). The allometric length-weight relation was as follows: weight $= 1.790 \times 10^{-4} \times \text{Length}^{2.948}$, $r = 0.932$ (Figure 3).

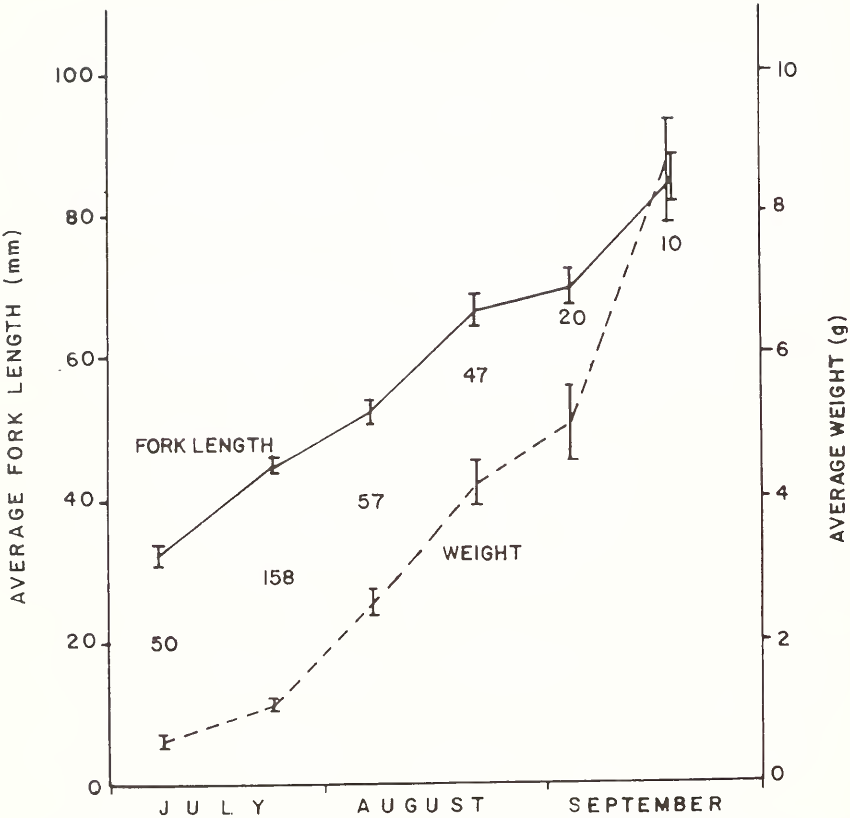

FIGURE 2. Size of young-of-the-year smallmouth bass from Clair Engle Reservoir California, July–September 1979. Mean ± standard error; numbers between weight and length curves show numbers of fish in each collection.

TABLE 2. Mean Size of Young-of-the-Year Smallmouth Bass from Clair Engle Reservoir, California, Summer 1979.

	July			*August*			*September*		
Habitat	*Length (mm)*	*Weight (g)*	*N*	*Length (mm)*	*Weight (g)*	*N*	*Length (mm)*	*Weight (g)*	*N*
1	42.1	1.2	107	54.3 [a]	2.4 [b]	39	72.0 [a]	5.9 [c]	11
2	46.1	1.5	55	62.6	3.7	27	77.4	6.7	8
3	46.6	1.5	23	63.6	4.3	38	79.5	7.3	11

[a] Significantly shorter than fish from habitats 2 and 3 (SNK; $P<0.05$).
[b] Significantly lighter than fish from habitats 2 and 3 (SNK; $P<0.05$).
[c] Significantly lighter than fish from habitat 3 (SNK; $P<0.05$).

Food

Of the 327 fish stomachs collected, 96% contained food. Food was analyzed only from the 221 fish (68% of the total) that had full stomachs.

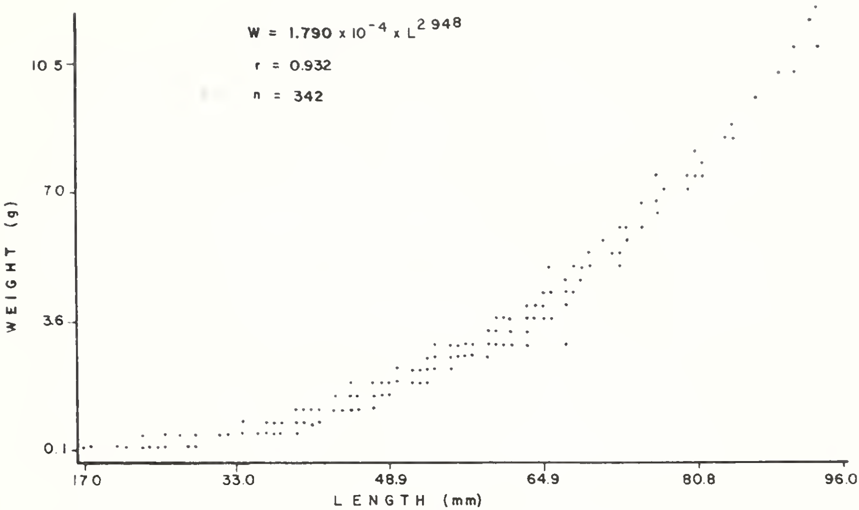

FIGURE 3. Length-weight relation of 342 young-of-the-year smallmouth bass from Clair Engle Reservoir California, July–September 1979.

Aquatic dipterans dominated the diet of age 0 smallmouth bass by volume, number, and frequency of occurrence (Table 3). Chironomid larvae dominated the food items by volume (49.5%), followed by Ephemeroptera (15.9%)—mostly nymphs of Baetidae. Chironomid pupae, the second most abundant dipteran, were the third most abundant food item by volume (11.0%). These three groups accounted for 76.5% of the volume of food eaten by age 0 bass.

Chironomid larvae dominated the diet by numbers (28.0%) and chironomid pupae ranked third numerically (15.0%). The copepod, *Diaptomus franciscanus*, ranked second numerically (22.2%), and the cladoceran, *Diaphanasoma brachyurum*, ranked fourth (12.8%). The other 33 food items accounted for only 22.8% of the total number of items eaten.

Frequency of occurrence for larvae and pupae of Chironomidae were 83.7 and 75.6%, respectively. They were followed by Cladocera, Ephemeroptera, and Copepoda.

Indices of Relative Importance and percentage IRI were determined for the 12 most important food categories (Table 4). The most important age 0 smallmouth bass food was chironomid larvae and pupae (IRI, 42 and 17%, respectively). The next two most important food items were *Diaptomus franciscanus* and *Diaphanasoma brachyurum*. These four food organisms accounted for at least 84% of the IRI each month. Chironomid larvae were the most important age 0 smallmouth bass food in all habitats in July, and in habitats 2 and 3 in August (Table 4). *Eurycercus lamellatus* was the most important food item in August in habitat 1. The most important food organisms in September were *Diaptomus franciscanus* in habitat 1, *Diaphanasoma brachyurum* in habitat 2, and chironomid pupae in habitat 3.

TABLE 3. Stomach Contents of 221 Young-of-the-Year Smallmouth Bass from Clair Engle Reservoir, California, July–September 1979.

	Volume		*Number*		*Occurrence*	
Food Items	*ml*	*%*	*N*	*%*	*Frequency*	*%*
Ceriodaphnia laticaudata	T [a]	T	38	0.2	3	1.4
Chydorus sphaericus	T	T	105	0.5	34	15.4
Daphnia galeata mendotae	0.14	1.1	1392	6.3	17	7.7
Daphnia pulex	0.08	0.6	548	2.4	55	24.9
Diaphanasoma brachyurum	0.28	2.2	2770	12.6	108	48.9
Eurycercus lamellatus	0.39	3.1	1951	8.9	122	55.2
Polyphemus pediculus	T	T	215	1.0	4	1.8
Diaptomus franciscanus	*0.49*	*3.9*	*4900*	*22.2*	*64*	*29.0*
Cyclops bicuspidatus	T	T	159	0.7	39	17.6
Ostracoda	T	T	2	T	1	0.5
Amphipoda	0.08	0.6	109	0.5	15	6.8
Heptageniidae (nymphs)	T	T	1	T	1	0.5
Caenidae (nymphs)	T	T	1	T	1	0.5
Baetidae (nymphs)	1.98	15.9	238	1.1	80	36.2
Gomphidae (nymphs)	0.13	1.0	9	T	1	0.5
Libellulidae (nymphs)	0.14	1.1	5	T	3	1.4
Zygoptera—damselflies	0.51	4.1	41	0.2	30	13.6
Corixidae	T	T	5	T	3	1.4
Leptoceri	0.02	0.2	16	0.1	5	2.3
Chironomidae (larvae)	6.17	49.5	6171	28.0	185	83.7
Chironomidae (pupae)	1.37	11.0	3294	15.0	167	75.6
Dixidae	T	T	1	T	1	0.5
Muscidae (larvae)	T	T	2	T	1	0.5
Brachycera	T	T	1	T	1	0.5
Corydalus sp. (larvae)	0.16	1.3	8	T	7	3.2
Dytiscidae (larvae)	T	T	3	T	3	1.4
Cleridae	T	T	1	T	1	0.5
Eupelmidae	T	T	2	T	1	0.5
Formicoidae	T	T	1	T	1	0.5
Chalcidoidae	T	T	1	T	1	0.5
Emphididae	T	T	10	T	3	1.4
Mycetophilidae	T	T	1	T	1	0.5
Cicadellidae—leafhoppers	T	T	1	T	1	0.5
Psyllidae (Chermidae)	T	T	2	T	1	0.5
Delphacidae	T	T	1	T	1	0.5
Ictalurus sp.	0.17	1.4	5	T	3	1.4
Green Sunfish	0.17	1.4	5	T	3	1.4
(*Lepomis cyanellus*)	0.06	0.5	2	T	2	0.9
Trout or Kokanee	0.30	2.4	12	0.1	8	3.6
Unidentifiable items	T	T	—	—	—	—
Total	12.47	99.9	22024	99.8		

[a] T = (<0.05 ml or < 0.1%)

The number of food items in the stomachs of young fish decreased from July to September. However, the size of the organisms eaten increased. For example, as bass increased in size during the season they ate larger food items such as fish and damselflies.

TABLE 4. Index of Relative Importance of Major Food Items in the Diet of 221 Young-of-the-Year Smallmouth Bass from Clair Engle Reservoir, California, Summer 1979. Percent IRI in parentheses.

	July			*August*			*September*		
	habitat			*habitat*			*habitat*		
Food Item	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Chironomidae (larvae)	2979(29)	15270(86)	14119(83)	458(5)	8251(58)	7540(50)	343(3)	1867(15)	2370(14)
Chironomidae (pupae)	495(5)	961(5)	1982(12)	782(8)	4114(29)	4435(30)	371(3)	764(6)	8181(48)
Diaptomus franciscanus	6(T)[b]	0(0)	116(1)	2394(25)	483(3)	804(5)	10724(81)	1947(15)	72(T)
Diaphanasoma brachyurum	1532(15)	50(T)	35(T)	181(2)	725(5)	1636(11)	183(1)	7911(62)	4970(29)
Eurycercus lamellatus	1523(15)	97(1)	60(T)	4290(44)	61(T)	131(1)	480(4)	180(1)	345(2)
Baetidae (nymphs)	2735(26)	1159(7)	546(3)	639(7)	15(T)	309(2)	51(T)	0(0)	25(T)
Daphnia pulex	189(2)	1(T)	5(T)	333(3)	120(1)	16(T)	378(3)	4(T)	45(T)
Zygoptera (Damselfly)	583(6)	113(1)	5(T)	0(0)	24(T)	28(T)	0(0)	0(0)	0(0)
Daphnia galeata mendotae	146(1)	0(0)	0(0)	265(3)	363(3)	11(T)	0(0)	0(0)	0(0)
Trout or Kokanee	0(0)	2(T)	60(T)	0(0)	22(T)	69(T)	0(0)	0(0)	0(0)
Amphipoda	1(T)	0(0)	90(1)	0(0)	0(0)	12(T)	0(0)	0(0)	1110(6)
Leptoceridae	0(0)	0(0)	0(0)	0(0)	1(T)	0(0)	519(4)	0(0)	4(T)
Others[a]	203(2)	14(T)	0(0)	396(4)	0(0)	4(T)	126(1)	0(0)	0(0)
Total	10392	17667	17018	9738	14179	14995	13175	12673	17122

[a] *Polyphemus pediculus,* Libellulidae nymphs, Green Sunfish, Gomphidae nymphs, *Ictalurus,* and *Corydalus.*
[b] T = (< 0.5%).

DISCUSSION

The mean size of age 0 smallmouth bass was the same in all habitats in July. In August and September fish caught in habitats 2 and 3 were significantly larger than fish caught in habitat 1. Age 0 bass probably moved from more protected nearby areas into more exposed habitats as they grew and as weather conditions moderated later in the summer. Habitats 2 and 3 (especially 3) were exposed to wave action, and turbidities were high during the windy spring and early summer. These conditions are generally not suitable for small bass and they avoid such areas (Tester 1930, Hubbs and Bailey 1938, Latta 1963).

First-year growth of smallmouth bass in Clair Engle Reservoir was poor in comparison with growth in other areas (Carlander 1977). Age 0 bass averaged only 87 mm TL by 18 September 1979. Carlander reported lengths of 91 mm or longer for September. Age I bass from Clair Engle were smaller than 35 of the 38 entries for age I smallmouth bass reported by Carlander (1977). Most age I fish cited by Carlander were considerably longer (mean 166 mm; range 41-343 mm) than the mean TL of 105 mm for age I smallmouth bass from Clair Engle Reservoir reported by Hannah (1980). Clair Engle Reservoir is deep, cold, and unproductive, and these characteristics may account for the poor first-year growth. Tharratt (1966) reported that age I smallmouth bass from Folsom Reservoir, California, were 149 mm long.

Preliminary data (J. Thomas upubl. data) indicated that first-year growth of smallmouth bass in Clair Engle Reservoir was very good, but more recent data indicated that bass growth rates decreased during the years after impoundment. Hannah (1980) working with adult bass from Clair Engle, found that age I smallmouth bass from 1967 through 1969 were larger than age I fish from 1970 through 1978, and growth of older bass had declined through the 1970's. The observed decrease in growth may be due to low plankton populations (Coleman 1978), reservoir aging (Neel 1967), or both.

Aquatic insects made up the largest part of the diet of young bass, followed by crustaceans and fish. Chironomid larvae were by far the most important source of food and chironomid pupae the second most important food at Clair Engle Reservoir in 1979. Several other investigators have also found that chironomidae were an important food of young-of-the-year smallmouth bass (Wickliff 1920, Pflieger 1966, Keating 1970). Baetidae nymphs were the third most important aquatic insect, although they ranked sixth in importance overall. The Chironomidae and Baetidae accounted for 79% of the total IRI.

Crustaceans, the second most important group of food organisms eaten by bass, consisted of copepod *Diaptomus franciscanus*, the most important item, and the cladoceran *Eurycercus lamellatus*, the second most important. Our findings also agree with findings of Wickliff (1920), Hubbs and Bailey (1938), Doan (1940), Lachner (1950), and Pflieger (1966), which showed that Copepoda were the most important zooplanters eaten by young bass and that Cladocera ranked second.

Fish was the third most important food item of young bass. They were not eaten until bass were 31 mm long or longer and were important in the diet of age 0 fish caught only in habitats 2 and 3. Pflieger (1966) found that in Missouri's small Ozark streams fish were important food items for bass longer than 15 mm

standard length (SL) and Wickliff (1920) indicated that fish were not an important food source until young bass were longer than 15 mm SL, but increased in importance as bass grew larger.

The diets of age 0 smallmouth bass in Clair Engle Reservoir were intermediate between those reported by Surber (1940), Lachner (1950), Pflieger (1966), Keating (1970) and Paragamian and Coble (1975) for riverine situations, and those reported by Wickliff (1920), Tester (1932), and Clady (1974) for lacustrine situations. Young smallmouth bass from the reservoir had a broad based diet consisting of food from six or more taxa. Aquatic insects were the major food source in this study, complemented by crustaceans, fish, and terrestrial insects. Keating (1970) reported similar diets in Idaho, where aquatic insects, terrestrial and flying aquatic insects, plankters, nematodes, and fish constituted the diet of young bass. Few terrestrial insects were available in Clair Engle Reservoir, perhaps due to the lack of overhanging vegetation along the shoreline.

Stomach content varied considerably by bass size, season, and habitat type. For example, chironomid larvae were less important in September than earlier, but chironomid pupae were more important in September. This change probably reflects the metamorphosis of larvae to pupae. *D. franciscanus* was a less important food item when bass were small (18 to 71 mm FL) in July than during September, when bass were larger (57–96 mm FL).

Young bass fed most of the time, as indicated by the small number of empty stomachs (only 4%). Similarly, few age 0 bass with empty stomachs were found by Wickliff (1920) or Harlan and Speaker (1956). In addition to continual feeding, many age 0 bass tended to feed on only one food at a time. For example, some stomachs might contain only *Diaptomus,* in numbers ranging from a few to hundreds. Beeman (1924) also observed a similar tendency of small bass to feed on only a single food item.

No fish were collected after September 1979 even though additional sampling was done in April and May 1980. This failure to collect fish of the 1979 year class in 1980 may indicate a change in distribution or heavy overwinter mortality or both. The 1979 year class fish may have moved from the sampling sites to other locations during the period between September and April. However, many bass of the 1977 and 1978 year classes (ages II and III) were caught in April and May 1980. Thus a change in vulnerability to the collecting gear was probably not a major factor. Age 0 smallmouth bass from Clair Engle were still small by late September and may have suffered high winter mortality. Christie and Regier (1973) and Oliver, Holeton, and Chua (1979) indicated that overwinter mortality was greater for small bass than for larger ones. Many of the smallest fish became emaciated, then lost equilibrium and died. Shuter *et al.* (1980) indicate that large bass can withstand winter starvation better than small fish and that high mortality of young bass may result from exposure to extreme temperatures.

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LIFE HISTORY OF THE SACRAMENTO SUCKER, *CATOSTOMUS OCCIDENTALIS,* IN THOMES CREEK, TEHAMA COUNTY, CALIFORNIA [1]

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The life history of the Sacramento sucker, *Catostomus occidentalis,* in Thomes Creek is described. Migration of adult spawning suckers began in December and peaked during the first week in March. It was comprised of fish ages 4 to 12, with a male-to-female ratio of 2:1. Spawing checkes on scales revealed that 89% were repeat spawners. Most spawning took place during the latter part of March. Hatching and peak outmigration of the juveniles occurred 4 to 5 wk after peak spawning. Peak outmigration of young-of-the-year suckers lasted for 3 wk. Growth of Sacramento suckers was rapid during their first 4 yr, then slowed in older fish. They matured sexually at age 4 to 7, but more commonly at ages 5 and 6 for males and ages 6 and 7 for females. The mean egg counts for 50 females averaging 429 mm in fork length equaled 16,358 with a range of 9,687 to 32,335. Diet of suckers throughout a 1-yr period varied slightly with algae and detritus the most prevalent food items (45%); sand composed 43% of the stomach contents while less than 10% of the diet consisted of insects, mainly larval plecopterans and dipterans.

INTRODUCTION

Sacramento suckers, *Catostomus occidentalis,* are native to the Sacramento-San Joaquin River system. Their distribution in California is well documented (Snyder 1905, Rutter 1908, Fowler 1913, Hubbs and Wallis 1948, Kimsey and Fisk 1964, Burns 1966*a*, Hopkirk 1973, Moyle and Nichols 1973, Moyle 1976). They are bottom feeders and dwellers and occur in a variety of habitats in lakes, streams, and large rivers. They are commonly found in habitats of many important game fish, and although some consider them a nuisance in trout streams, they are not considered as serious competitors (Dill and Wales 1945). They are caught incidentally by sport fishermen and are a very minor portion of the commercial catch of nongame fishes in California (Davis 1963).

They are perhaps the most abundant species of fish in Thomes Creek and are one of the most important forage bases for fish and wildlife in the Sacramento River system. In Thomes Creek and other tributaries to the Sacramento River, wintering bald eagles, *Haliaeetus leucocephalus,* and other wildlife feed on adult suckers (E. Smith, Dept. Fish and Game, pers. commun.), while juveniles are eaten by white sturgeon (Skinner 1956), striped bass (Dept. Fish and Game, Contract Services Section files), Sacramento squawfish (Burns 1966*b*), and other game and nongame fishes.

A few studies have dealt with the life history of the Sacramento sucker. Brauer (1971) and Ashley (1974) presented data on age and growth and feeding habits of the sucker. Brauer's food habit study, however, is based only on a collection from Hat Creek on one day, while Ashley's study deals mainly with summer

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feeding habits of suckers from the upper Eel River. Burns (1966*a*) collected fecundity, diet, age and growth data from suckers from the Merced River. Moyle (1976) compiled data from numerous authors as well as his own on the life history and ecology of the Sacramento sucker.

This study describes aspects of the spawning migration, juvenile outmigration, age, growth, and diet. It is the first major report on the life history of the Sacramento sucker.

STUDY AREA

Thomes Creek originates on the east side of the Coast Ranges and flows approximately 110 km along the southern border of Tehama County to the Sacramento River near the town of Tehama (Figure 1). It drains an area of approximately 500 km^2 above the town of Paskenta. Precipitation averages about 1,000 mm/yr. Mean annual discharge is 249,000 dam^3 (Brown 1980). Although there are no major storage and diversion structures within the basin, small amounts of water are diverted for irrigation, municipal, and industrial uses. During the summer, usually about June or July, outflow at the mouth ceases and the lower portion of the creek between the mouth and Paskenta becomes a series of pools ranging in depth from a few centimetres to about 2 m. Outflow begins after the first appreciable rains, typically during November or December.

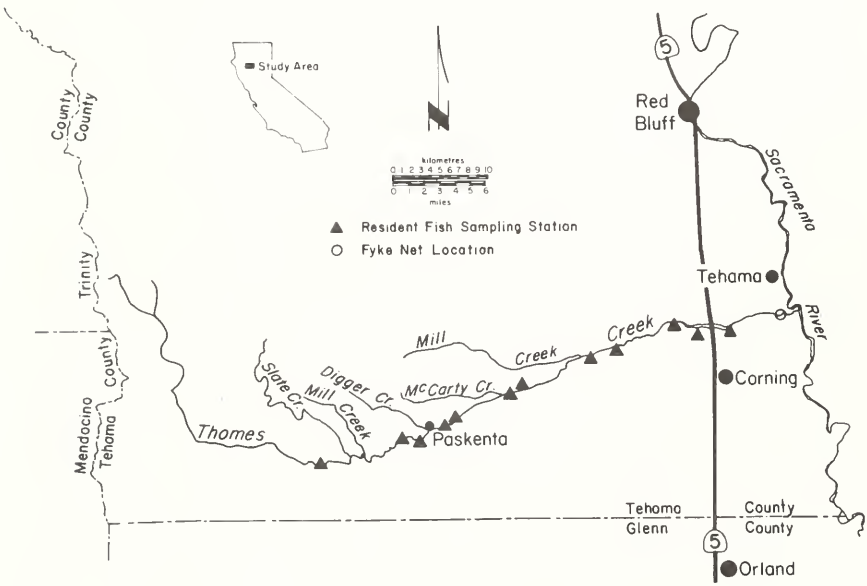

FIGURE 1. Thomes Creek, Tehama County.

METHODS AND MATERIALS

Age and Growth

Scale samples from suckers were taken from the left side between the lateral line and the dorsal fin. Scales were mounted dry between glass slides and their images projected at a magnification of 10×. Annuli were identified in the same

manner as Spoor (1939) and Ovchynnyk (1965). Scales from 268 fish of representative size groups captured during the months of February and March 1981 were used for aging while 2000 scales from adult fish caught during the spawning migration were used for spawning check counts. Spawning checks were identified by abrupt direction changes of the radii and wide gaps between circuli. Anterior radii of the scale and annuli were measured along a line 30° from the anterior-posterior axis. A linear regression was computed for the enlarged scale radius versus the fork length:

$$L = a + b\,Sc$$

where, L = fork length (mm)
Sc = enlarged scale radius (mm)
a = y − intercept
b = slope

Fork lengths were backcalculated using the formula (Carlander, 1969):

$$Ln = a + \frac{Sn}{Sc}(Lc - a)$$

where, Ln = length of fish at time of annulus
Lc = length at time of capture
Sn = scale measurement to a given annulus
Sc = scale measurement to edge

Reproduction

Population Estimate of the Spawning Migration

Adult Sacramento suckers were captured in Thomes Creek between RK 1.9 and RK 44.3 and in the lower 2 km of Mill Creek, a tributary at RK 24 (Figure 1). From December 1980 through June 1981, 17 samples were taken at 10-d intervals.

Fish were captured by drift electrofishing. A 3.7-m Avon rubber raft was fitted with a Smith-Root type VII electroshocker. The battery and electroshocking unit were placed inside an ice chest and secured to the raft's rowing frame. Probe arrays were constructed of 2-mm stainless steel cable and attached to the bow of the raft and fished at a depth of 1.5 m.

Each fish was weighed to the nearest 8 g and its fork lenth (FL) measured to the nearest 1 mm. Sex and spawning condition (green, ripe, or spent) were noted. Males were readily identified by the presence of nuptial tubercles located on the anal, pelvic, and caudal fins and on the ventral side of the caudal peduncle.

Each fish was marked with a Floy spaghetti tag and released. The tag was inserted under the dorsal fin and tied in a loop. Moribund individuals were not tagged but were saved for stomach, gonad, and ovary samples.

The method of Jolly-Seber (Seber 1973) was used to estimate the population and tag ratios from the mark and recapture data.

Fecundity

Intact ovaries from 50 mature females of various lengths were taken. Right and left ovaries were identified, placed in 20% formalin and allowed to harden for at least 48 h. Fecundity was then determined by the volumetric method (Lagler 1959).

A MINC multilinear regression program was used to determine the relationship between the length and weight of the fish and total egg counts as well as ovary weight.

Juvenile Emigration

Juvenile and larval suckers emigrating to the Sacramento River were captured with a fyke net constructed of 0.8-mm oval mesh netting mounted on a 0.3-m × 0.6-m square metal tubing frame. It was placed in the creek near the mouth of Thomes Creek (RK 1.9). The net was fished 24 h/d on weekdays from January to June 1981. It was checked once daily.

The fork length of each fish was measured to the nearest 1 mm. The standard length of larval fish was measured to the nearest 0.5 mm and converted later to fork length by extrapolating from a regression of fork length versus standard length ($FL = 1.908 + 0.895\ (SL)$, $r = 0.99$, $n = 500$, where FL = fork length and SL = standard length). Larval suckers were defined as those fish that had not developed a subterminal mouth or a forked caudal fin.

Resident Fish

During July, August, and September 1981, 12 stream sections in the main stem of Thomes Creek, varying in length from 20 m to 90 m, were electroshocked for resident suckers. Populations were estimated using the two-pass removal method of Seber and LeCren (1967).

Length-Weight Relationship

The length-weight relationships for spawning suckers and suckers of all ages were determined from the equation $\log w = \log a + b\ (\log l)$; where, l = millimetre fork length, w = gram weight (Ricker 1975).

Analysis of covariance (Snedecor and Cochran 1967) was used to test the differences between the regression lines for spawning suckers that were green, ripe, or spent.

Condition factors were calculated using the formula $K = {}^{w}/l^{3} \times 10^{5}$, where, l = millimetre fork length, w = gram weight (Lagler 1959).

Diet

Stomachs were excised from 160 suckers (40 per season) of various lengths and stored in 70% alcohol. Since there is no true stomach in suckers, the stomach was defined as the foregut in front of the first bend to the esophagus (Macphee 1960, Hauser 1969). Contents of stomachs from each season were sorted and identified (Borgeson 1966). Insects were identified to order, samples oven-dried at 70 °C for 24 h, then weighed to the nearest 0.001 g.

RESULTS AND DISCUSSION

Age and Growth

Annulus formation occurred over a 4-month period. For most fish aged less than 4 yr, annulus formation usually occurred during January and February, whereas older, sexually mature fish began formation of the annulus and spawning check during March and April. In a study of longnose suckers, *Catostomus catostomus,* in Lake Superior, Bailey (1969) found that annulus formation extended over a 2-to-4-month period and varied with age of fish and year of collection. False annuli were occasionally found on scales between the focus

and the first annulus. These false annuli did not have as many circuli crowded together nor were they continuous in the lateral fields as in a true annulus. I theorize that some of these false annuli were caused by high temperatures and crowded rearing conditions that are characteristic of many westside tributaries to the Sacramento River.

The relationship between scale radius and fork length of 268 suckers was linear and is described by the equation $FL = 56 + 0.4675\,(S)$, $(r = 0.97)$, where, FL = fork length and S = enlarged scale radius. The intercept of 56 mm was used for backcalculating lengths at each successive annulus. Brauer (1971) calculated an intercept of 59.9 mm for Sacramento suckers in Hat Creek.

Aging showed that the population consisted of suckers aged 0 through 12 (Table 1). Increments of growth generally decreased after the first year of growth. Males and females did not significantly differ in growth and, therefore, were combined for growth calculations (analysis of covariance $p < 0.05$). In white suckers, *Catostomus commersoni,* and longnose suckers, females grew faster than males (Spoor 1939, Raney and Webster 1942, Elsey 1946, Harris 1952, and Hayes 1956); however, Harris (1962) found no difference in growth between males and females. For Thomes Creek suckers, I aged females up to 12+ while no male was found over 9+. Brown and Graham (1954) found that female longnose suckers live longer and Geen *et al.* (1966) suggest that females live longer than males.

Comparison of growth curves of Sacramento suckers from Hat Creek (Bauer 1971), Merced River (Burns 1966*a*), Cottonwood Creek (Dept. Fish and Game, Contract Services Section files), Feather River (Moyle, Vondracek, and Grossman 1983), and Thomes Creek shows that growth among different populations can be variable (Figure 2), reflecting the variability of a number of factors such as temperature, water quality, food availability, and population density (Eddy and Carlander 1940).

Population Estimate and Timing of the Spawning Migration

The first adult Sacramento sucker was captured and tagged on 10 December 1980. The first tagged sucker was recovered on 30 December 1980. The population for this time period was estimated at 440 fish (Table 2). Estimates for the migration rose erratically until the first week of March at which time the estimate peaked at over 240,000 fish. Recoveries of tagged fish were so low that estimates of the population may be misleading. Estimates are based on 2,081 tagged suckers of which only 41 were recovered.

Between the last week in February to the end of March, most of the spawning population had entered the system and soon afterwards reached their peak in ripeness level. Percentage composition of ripe fish in the population shows that ripeness level was highest during early March through late April with a peak in ripeness during the last week in March (Figure 3). Another prominent but lesser peak in the percentage composition of ripe fish occurred in late April. These peaks may reflect increases in the population estimates for sample periods ending on 9 March and 8 April, respectively (Table 2).

TABLE 1. Age and Backcalculation of Fork Lengths of Sacramento Suckers from Thomes Creek, Tehama County, 1981

Age	Number of fish	Mean length at capture (mm)	Calculated length at each annulus (mm)											
			1	2	3	4	5	6	7	8	9	10	11	12
0	34	60												
1	48	119	98											
2	13	189	102	153										
3	7	255	105	156	212									
4	18	339	111	172	247	310								
5	40	378	112	170	237	303	353							
6	37	396	105	154	220	283	336	374						
7	26	414	104	151	217	275	319	360	393					
8	19	439	108	154	212	284	328	369	398	422				
9	13	461	106	166	219	279	333	369	399	423	441			
10	8	462	113	146	193	262	310	352	384	408	427	447		
11	3	490	110	152	206	275	335	363	393	419	443	456	472	
12	2	475	98	143	194	232	309	341	372	394	413	434	448	460
Total	268	WMI	106	159	223	288	335	367	394	418	435	447	462	460
			106	56	64	65	47	32	27	24	17	12	15	−2

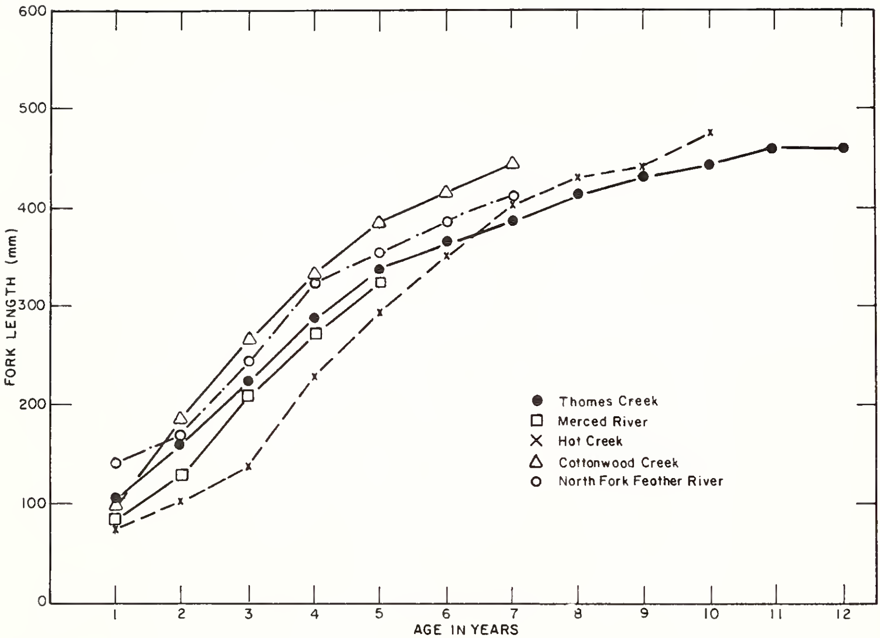

FIGURE 2. Comparison of growth curves of Sacramento suckers from Hat Creek, Cottonwood Creek, Merced River, North Fork Feather River and Thomes Creek.

TABLE 2. Jolly-Seber (Seber 1973) Spawning Population Estimates of Sacramento Suckers from Thomes Creek, Tehama County, California, 1981

Sample period ending	*Number of fish tagged*	*Number of tags recovered*	*Population estimate*
12-09-80	0	—	—
12-19-80	26	0	—
01-08-81	44	2	440
01-18-81	32	3	715
01-28-81	66	1	8,808
02-17-81	210	1	22,083
02-27-81	30	1	3,634
03-09-81	722	2	241,481
03-19-81	473	5	55,000
03-29-81	51	7	1,938
04-08-81	280	8	41,168
04-18-81	115	4	8,818
04-28-81	16	1	1,548
05-08-81	4	1	5
05-18-81	13	4	13
05-28-81	0	1	10
06-07-81	0	0	0
Totals	2,081	41	

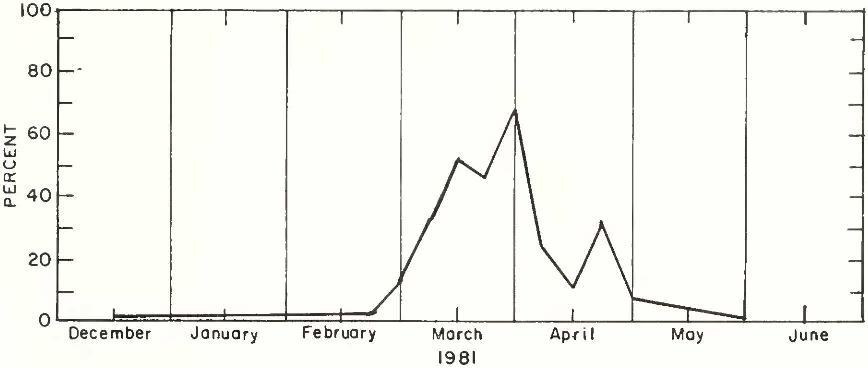

FIGURE 3. Percent ripe Sacramento suckers from Thomes Creek, Tehama County, 1981.

During the spawning migration, the sex of 2,086 adult suckers was identified. Six hundred twenty-eight of these were females, while 1,428 were males, representing a sex ratio of 1:2.17. The mean fork length of females (428 mm) was significantly larger than males (383 mm) ($p < 0.05$) (Figure 4). In Cottonwood Creek, male Sacramento suckers average 396 mm while females averaged 431 mm (Dept. Fish and Game, Contract Services Section files). Females of both white suckers and longnose suckers averaged larger than males (Elsey 1946, Harris 1962, Geen *et al.* 1966).

Age Structure and Sexual Maturity

The scales of 2,000 spawning suckers were examined and assigned ages and number of spawning checks (Table 3). The spawning population consisted of males aged 4 through 9 and females aged 4 through 12 (Table 3). For males, ages 5 and 6 composed the majority of spawners, while spawning females were mainly composed of ages 6 and 7. The age-frequency was somewhat similar in distribution and character to the length-frequency of spawning adult suckers, suggesting that assignment of ages was fairly accurate and that length and age in Sacramento suckers are closely related.

Spawning checks were observed in 89% of the males and 96% of the females. At least half of the population spawned twice, while many fish spawned up to four times (Table 3). Geen *et al.* (1966) showed that longnose and white suckers are repeat spawners.

The data showed that sexual maturity can be attained at age 4 (8%), but most suckers attained sexual maturity at age 5 or 6 (Table 4). Moyle (1976) states that the Sacramento sucker can mature sexually at 4 or 5 yr, while the longnose sucker can mature at 2 or 3 yr of age (Hayes 1956). Brown and Graham (1954) found that longnose suckers usually mature at age 4, whereas white suckers generally mature in their third or fourth year (McCrimmon and Berst 1961). Campbell (1935) showed that white suckers from Waskesiu Lake, Saskatchewan, matured as late as ages 6 to 9. The oldest any fish first became sexually mature for my population was at age 7. This occurred for less than 4% of the population.

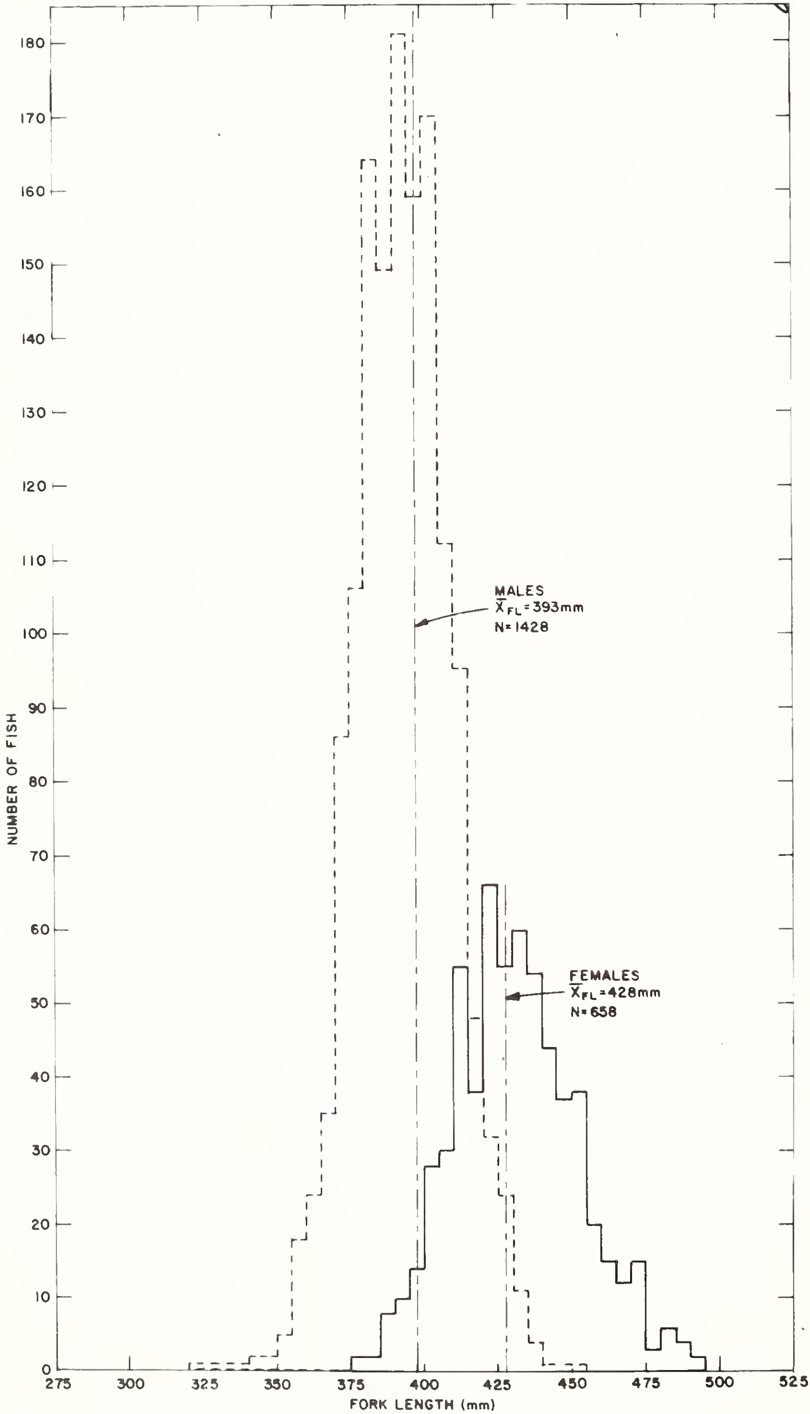

FIGURE 4. Length-frequency of spawning adult Sacramento suckers from Thomes Creek, Tehama County, 1981.

TABLE 3. Spawning Check Counts on Scales from Sacramento Suckers in Thomes Creek, Tehama County, 1981

	Female spawners at age (percent composition)										*Male spawners at age (percent composition)*					
Number of spawning checks	*4+*	*5+*	*6+*	*7+*	*8+*	*9+*	*10+*	*11+*	*12+*	*Number of spawning checks*	*4+*	*5+*	*6+*	*7+*	*8+*	*9+*
0	1.4	1.4	1.0							0	4.1	5.4	1.3			
1	0.5	9.7	9.2	0.5						1	1.3	17.1	14.6	0.3		
2		2.4	9.2	12.6	1.9					2		2.2	21.9	7.6	0.3	
3			2.9	12.5	6.3	1.0				3			3.2	10.2	3.2	0.3
4				1.9	8.7	4.8	0.5			4				1.6	4.4	0.3
5						5.8	2.4	0.5		5						0.6
6							1.4	—	0.5							
7								0.5	0.5							
Totals	1.9	13.5	22.2	27.4	16.9	11.6	4.3	1.0	1.0	Totals	5.4	24.8	41.0	19.7	7.9	1.4

TABLE 4. Age at Which First Spawning Check was Observed in Scales from Sacramento Suckers from Thomes Creek, 1981

	Age (percent composition)			
Sex	*4+*	*5+*	*6+*	*7+*
Female	7.7	49.2	37.2	5.9
Male	8.3	58.3	31.1	2.2
Weighted Percent	8.1	55.5	33.0	3.4

Fecundity

The egg counts for 50 females (X/FL = 429 mm) were highly variable with a mean of 16,358 and a range of 9,687 to 32,335 (Table 5). Sacramento suckers ranging in size from 280 mm to 380 mm FL from Alpine Lake, Marin County, contained 4,720 to 10,932 eggs (Burns 1966*a*). Sacramento suckers from Cottonwood Creek had egg counts ranging from 10,840 to 22,636 for 17 fish ranging in size between 411 mm to 485 mm FL (Dept. Fish and Game, Contract Services Section files). Although the trend appears to be for longer and heavier fish to have more eggs, I found no strong correlation between any body measurement and egg counts or ovary weight for suckers from Thomes Creek (Figure 5). In Tahoe suckers, *Catostomus tahoensis*, fecundity was also highly variable (Willsrud 1971), and had a weak linear correlation with fork length (Moyle 1976).

TABLE 5. Fecundity of Sacramento Suckers from Thomes Creek, Tehama County, 1981

By Length Interval					*By Weight Interval*				
Fork length (mm)			*Number of eggs*		*Weight (g)*			*Number of eggs*	
Interval	*Mean*	*N*	*Range*	*Mean*	*Interval*	*Mean*	*N*	*Range*	*Mean*
300–349	326	1	—	10318	400– 499	550	1	—	10318
350–399	382	6	9687–16190	12005	600– 799	729	9	9687–18741	14666
400–449	427	30	11350–21614	15668	800– 999	905	16	10624–22672	15179
450–499	403	13	15488–32335	20437	1000–1199	1076	15	11527–21614	17656
					1200–1399	12515	8	18098–22741	20136
					1400–1599	1588	1	—	32335
Grand Mean or Total	429	50	9687–32335	16358	550–1588	987	50	9687–32335	16358

Sexual Dimorphism and Spawning Act

Sacramento suckers when not in spawning condition are dark brown, greenish, or almost black on their dorsal side, fading to a light or golden brown near the ventral side. During the spawning season, males developed small bumps or nuptial tubercles on their anal, pelvic, and lower caudal fins and on the ventral side of the caudal peduncle. As spawning time approached, these tubercles became more pronounced. During peak spawning, the nuptial tubercles were at their fullest development and appeared as bumpy white dots on the fish's surface.

Nuptial tubercles are presumably used by the males to "grip" the female during spawning (Branson 1961). I was unable to verify this claim although I observed males in close contact with the female during spawning.

In addition to the nuptial tubercles, the males developed a broad black or dark-brown stripe along the lateral line. This stripe was most prominent during spawning.

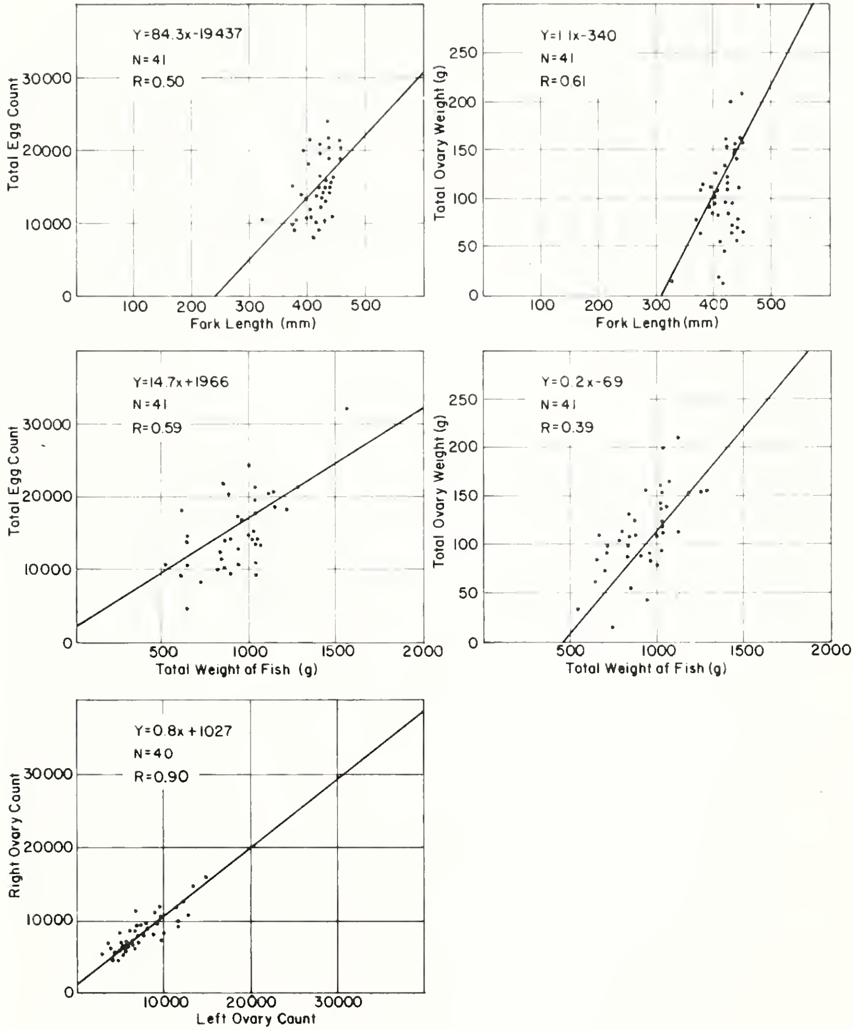

FIGURE 5. Linear regressions of fecundity, ovary weight and body measurements of Sacramento suckers from Thomes Creek, Tehama County, 1981.

During the spawning migration, some females were observed with well-developed pearl organs. They appeared as small pearl-like spheres on the anal, caudal, and pelvic fins. Very few males were observed with pearl organs.

The spawning act of Sacramento suckers is similar to that of the white sucker. Sacramento suckers generally spawn on shallow riffles in groups comprised usually of six to seven males centered around one or two females. Spawnings usually lasted no longer than 2 h. There also seems to be no preference for time of day or amount of light.

Eggs were adhesive, but usually they did not stick to the substrate; rather they picked up small bits of debris that allowed them to roll along the bottom with the current until they settled out among the interstices of the substrate or in the shallow stream margins where there was little or no current.

Juvenile Emigration

The bulk of the juvenile and larval sucker emigration from Thomes Creek to the Sacramento River occurred mostly during about a 3-wk period in late May and early June, but young emigrated in low numbers throughout the sampling period (Figure 6). Mean lengths and the length frequency distribution from February to April remained similar (Figure 7). These fish were probably spawned during the previous spring and remained in the creek throughout the summer until discharge was high enough for them to migrate downstream.

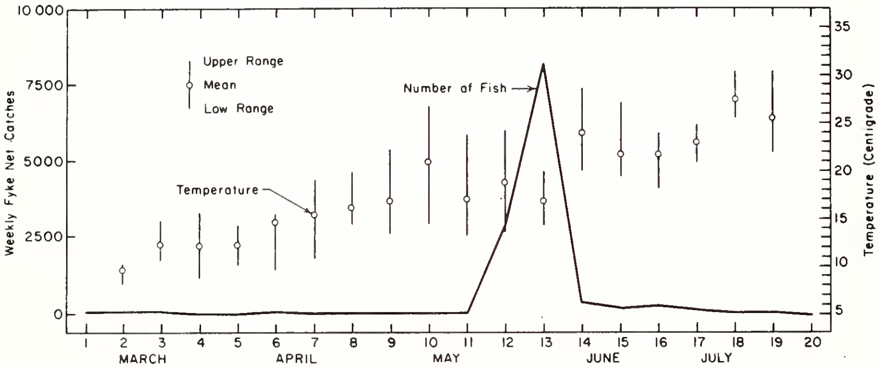

FIGURE 6. Weekly fyke net catches of juvenile Sacramento suckers emigrating from Thomes Creek to Sacramento River, 1981.

Larval suckers were first observed in the upper reaches of the main stem and tributaries in late April, but none was caught near the mouth until mid-May. The emigration at that time increased rapidly until the weekly fyke net catch peaked at over 7,500 fish during the first week of June (Figure 6). After the first week of June, catches diminished rapidly, but emigration continued for about 4 wk until there was no measurable discharge at the mouth of Thomes Creek.

The first larval suckers were observed in the creek about 4 to 5 wk after the first ripe adult suckers were observed. In addition, the peak in juvenile emigration occurred approximately 4 to 5 wk following the peak in spawning activity. Moyle (1976) and Burns (1966*a*) estimated that Sacramento suckers hatch in about 4 wk. This concurs with my observations.

Resident Fish

Sacramento suckers were found at all 12 stations during the summer, but population and biomass estimates varied widely (Table 6). At stations 1–11 suckers were usually the second most abundant species by numbers, and comprised from 1.5% to 39.6% of the total biomass. They were the most abundant species by number and biomass at Station 12. At stations 1–11 Sacramento squawfish was the most abundant species, with California roach, *Lavinia symmetricus,* and hardhead, *Mylopharodon conocephalus,* also present in significant numbers. Other fish captured in these stations included green sunfish, *Lepomis cyanellus;* bluegill, *Lepomis macrochirus;* largemouth bass, *Microterus*

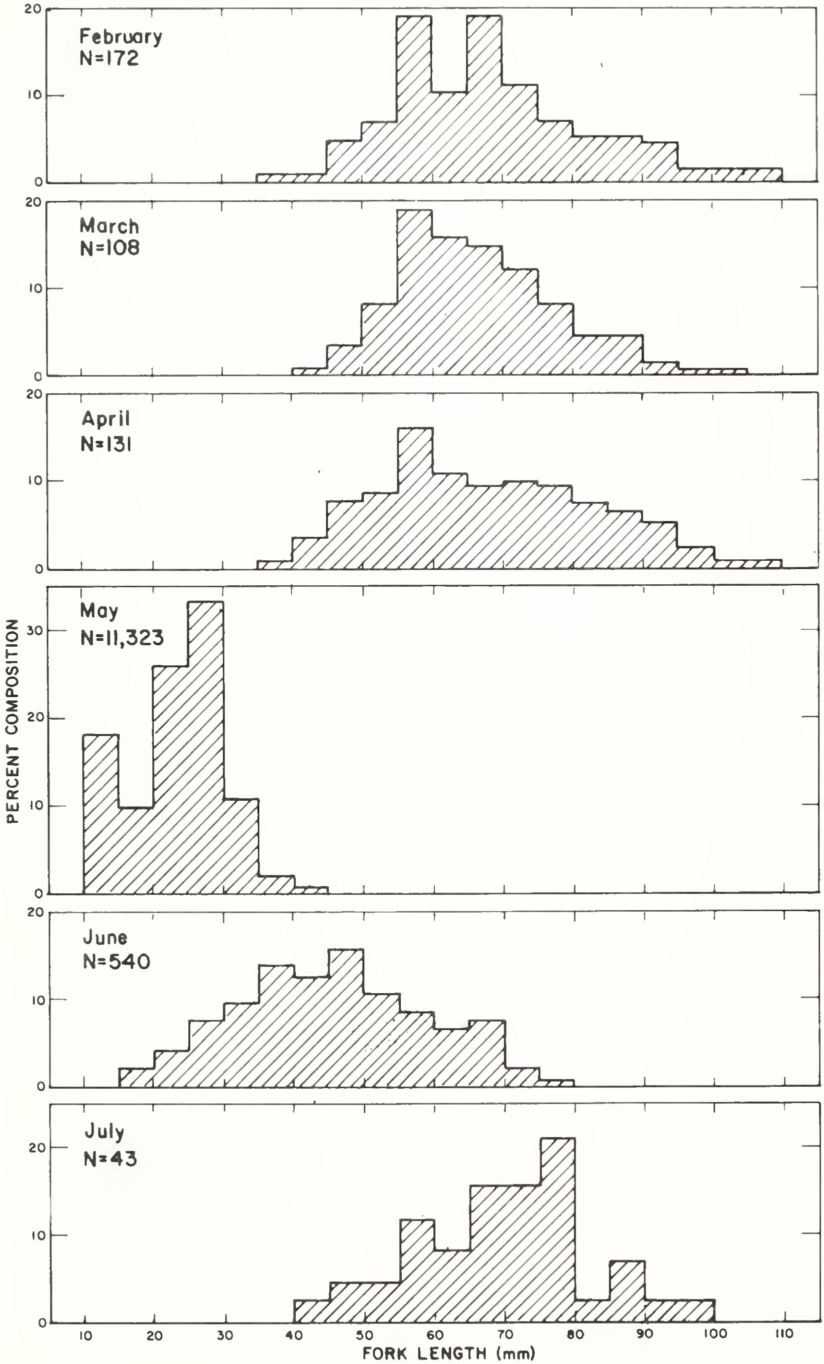

FIGURE 7. Length-frequency of juvenile Sacramento suckers emigrating from Thomes Creek, to the Sacramento River, 1981.

salmoides; hitch, *Lavinia exilicauda;* speckled dace, *Rhinichthys osculus;* carp, *Cyprinus carpio;* goldfish, *Carassius auratus;* prickly sculpin, *Cottus asper;* tule perch, *Hysterocarpus traski;* and rainbow trout, *Salmo gairdneri.* For all stations nongame fish were the most prevalent in numbers and biomass.

TABLE 6. Population and Biomass Estimates of Resident Sacramento Suckers in Selected Sections of Thomes Creek, Tehama County, 1981

Station number	*River kilometre*	*Population estimate (95% C.I.)*	*Biomass* g/m^2	*Biomass* g/m^3	*Percent of total fish biomass*
1	7.2	16 (13–19)	1.2	5.2	1.5
2	12.1	196 (191–200)	1.5	10.0	15.7
3	21.1	58 (56–59)	0.9	2.3	11.0
4	21.8	210 (208–214)	5.9	42.2	27.6
5	22.5	36 (1–89)	2.9	6.8	7.1
6	33.2	21 (20–22)	4.9	19.6	39.6
7	39.1	9 (8–10)	0.1	0.4	3.8
8	41.8	9 (8–10)	0.5	2.9	8.4
9	44.9	19 (16–21)	1.1	7.0	25.5
10	45.7	44 (34–54)	2.1	7.9	6.3
11	46.7	5 (5–5)	0.2	0.7	9.9
12	60.5	132 (119–146)	5.3	20.7	66.8

Most suckers sampled in my survey were juveniles; only a few spent or moribund adults were captured. In a survey of fishes in streams of the Sierra Nevada foothills, Moyle and Nichols (1974) found that a majority of Sacramento suckers were also juveniles, and that these small intermittent streams serve as nursery areas while the adults live in larger streams and reservoirs.

In my study this was also the case where adults resided in the Sacramento River and ascended Thomes Creek only to spawn. Most of the juveniles emigrated immediately after hatching and only those that are stranded or elected to stay were captured during the summer resident fish sampling.

Length-Weight Relationship

The length-weight relationship calculated for 246 suckers of all sizes was curvilinear and is described by the equation:

$$\text{Log}_{10} \text{ weight} = -4.9246 + 2.9962 \text{ Log}_{10} \text{ length } (r = .99)$$

(Figure 8). For this relationship, ripe or spent adult fish were not used.

A separate regression for each sex and stage of reproduction (green, ripe, or spent) for adult fish was calculated and compared (Table 7). Analysis of covariance showed that the slopes and intercepts of all regressions were not significantly different ($P < .05$).

TABLE 7. Linear Regressions of the Length-Weight (Log_{10}) Relationships of Adult Sacramento Suckers from Thomes Creek, Tehama County, 1981

Sex	*Spawning condition*	*Y-intercept*	*Slope*	*Number of fish*	*Correlation coefficient*
F	Green	−3.109	2.308	159	0.80
M	Green	−2.924	2.227	176	0.76
F	Ripe	−3.401	2.417	111	0.76
M	Ripe	−3.390	2.401	364	0.76
F	Spent	−3.185	2.304	158	0.82
M	Spent	−3.197	2.312	37	0.71

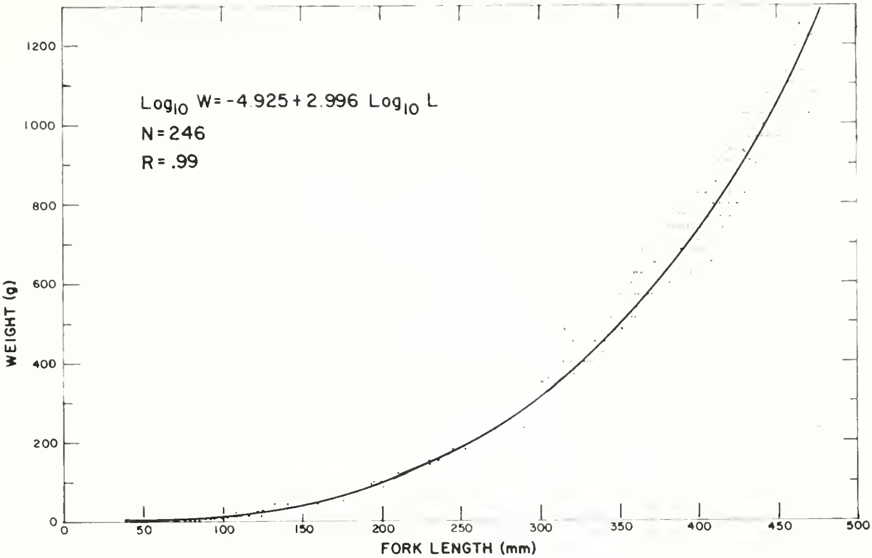

FIGURE 8. Length-weight relationship of Sacramento suckers in Thomes Creek, Tehama County, 1981.

The coefficient of condition was calculated for as many representative individuals per length group as possible (Table 8). Some groups and individuals were not available, yielding wide-ranging values, and, in some cases, no data. Therefore, a calculated value for each length group was derived from the length-weight equation. The calculated values represent the coefficient of condition for the midpoint of the length interval. The calculated values show that the coefficient decreases very slightly with increased length.

TABLE 8. Coefficient of Condition (K) for Sacramento Suckers, Thomes Creek, Tehama County, 1981

Fork length (mm)	*N*	*Mean weight (g)*	*Calculated weight (g)*	*Empirical — K*	*Calculated — K*
40–49	22	1.29	1.03	1.3450	1.1724
50–99	93	4.51	4.83	1.1719	1.1681
100–149	43	16.65	22.53	1.1372	1.1675
150–199	6	63.67	61.98	1.1211	1.1665
200–249	7	142.14	131.86	1.1846	1.1654
250–299	3	215.00	240.85	1.0802	1.1645
300–349	17	410.00	397.65	1.2147	1.1637
350–399	154	659.43	610.90	1.1948	1.1631
400–449	186	874.88	889.29	1.1489	1.1625
450–499	34	1092.36	1241.47	1.1089	1.1621

Diet

The diet of Sacramento suckers in Thomes Creek did not change seasonally throughout a 1-yr period (Table 9). Algae and detritus were the most prevalent food items (45%) while sand composed 43% of the stomach contents. Insects,

mainly larval plecopterans and dipterans, made up less than 10% of the diet. There was no pattern to the composition of insects consumed. Therefore, it is likely insects were only incidental food items.

TABLE 9. The Seasonal Diet Composition of Sacramento Suckers from Thomes Creek, Tehama County, California, 1981

	Percent Composition by Weight			
Food item	*December to February*	*March to May*	*June to August*	*September to November*
Ephemeroptera	2.13	0.01	0.26	0.73
Odonata	–	–	–	0.22
Plecoptera	15.86	–	0.03	1.19
Tricoptera	2.68	0.01	0.89	0.02
Hymenoptera	–	–	–	0.07
Coleoptera	–	0.02	–	0.17
Diptera	8.25	0.02	1.05	4.25
Algae and Detritus	33.40	50.13	51.39	36.10
Sand	34.57	49.70	45.55	54.57
Unidentified	3.11	0.11	0.83	2.68
Number of Stomachs Examined	40	40	40	40
Number of Empty Stomachs	7	18	5	6

Brauer (1971) found that algae was the most prevalent food item in larger suckers. In addition, Moyle (1976) states that the bulk of their diet is algae, diatoms and detritus. Hauser (1969) showed that mountain suckers ate mostly diatoms and algae.

CONCLUSIONS

Sacramento suckers have adapted well to the intermittent nature of Thomes Creek. Adults migrate upstream to spawn during high water and eventually the young hatch and the majority of them emigrate to the Sacramento River before low-flow periods restrict their downstream emigration. Hence, these fish utilize spawning habitat in intermittent streams and make use of habitat not normally available to other fish during short periods of rainfall.

I was not able to quantify the importance of suckers in relation to other species of fish and wildlife that may compete with or use them as food. Such studies are needed to assess these relationships. In addition, elements critical to their well being—such as flows, habitat, water quality, and other physical and biological requirements—need to be determined. This information has utility in determining impacts on suckers caused by man.

SUMMARY

1. Spawning population consisted of fish aged 4–12, with a majority of the spawners aged 5–7.
2. Female suckers were generally longer-lived and usually larger.
3. Adult suckers first entered Thomes Creek in December and peaked in numbers during March.
4. Ripeness level was highest during early March through late April.
5. Sex ratio of the spawning migration was 2.17 males to every female.
6. Sacramento suckers matured sexually at age 4 but most commonly at ages 5 and 6.

7. Fecundity ranged from 9,687 to 32,335 eggs/female with an average of 16,358 for 50 adult females (S_{FL} = 429 mm).
8. Sacramento suckers spawned in groups and broadcasted adhesive eggs.
9. Hatching time for Sacramento suckers was 4 to 5 wk.
10. Larval suckers were first observed in late April.
11. Emigration of juvenile and larval suckers was continuous when water flowed at the mouth. Most larval emigration occurred during May and June.
12. Sacramento suckers exhibited a curvilinear length and weight relationship: $\text{Log}_{10} = 4.9246 + 2.9246\ \text{Log}_{10}\ L\ (r = .99)$.
13. Sacramento suckers mainly ate algae and detritus while insects appeared to be consumed incidentally.

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NOTES

GROWTH OF GRASS CARP, *CTENOPHARYNGODON IDELLA,* IN ARTIFICIAL CENTRAL ARIZONA PONDS

Grass carp, *Ctenopharyngodon idella,* is a western Asian cyprinid transplanted widely throughout the world, primarily for control of nuisance aquatic vegetation (Cross 1969). It was introduced to the United States in 1963 (Stevenson 1965), and now is known from at least 34 states (Guillory 1980). The species was first stocked into Arizona waters in 1965 (Marsh and Minckley 1983*a*).

Because of its potential for aquatic vegetation control, growth and feeding dynamics of grass carp have received considerable attention (Venkatesh and Shetty 1978; Shelton, Smitherman, and Jensen 1981; Shireman and Maceina 1981). We are unaware of studies of North American populations that document annual growth in length beyond the second year, nor of any successful efforts to determine growth history from scale analysis. Pflieger (1978) aged 18 fish between ages II and V (?) from the Missouri River, but could not back-calculate lengths due to lack of accurate specimen data. We report annual growth as determined from examination of scales of grass carp in central Arizona.

METHODS

Grass carp were stocked in 1970 or 1971 (exact date unavailable) into seven small, artificial ponds at Sun Lakes, central Arizona. Specifications of ponds and their fish communities were reported by Marsh and Minckley (1983*b*). Size of fish at introduction reportedly was 152–203 mm. Ponds were reclaimed in April 1978 with rotenone. Grass carp were measured (TL, mm) and weighed (nearest 0.01 kg). Scales were removed from the left side ventral to the dorsal fin, cleaned, dried, mounted between glass slides, and examined independently by each of us at 15x on a Bausch & Lomb Tri-Simplex microprojector. The magnified total scale radius from focus to anterior margin and the anterior distance from focus to each annulus were measured (nearest mm). Regenerated scales were discarded. Fish lengths at consecutive annuli were back calculated by the formula $L' = S'/S\ (L)$ where L' is TL at annulus formation, L is TL at capture, S' is annular radius, and S is total scale radius. Least squares linear regression of S on L to obtain an intercept value "c" (approximation of TL at scale formation) gave a "nonsense" value because available data for L and S did not include a range sufficient to calculate a reliable expression. Therefore, no adjustment to the equation was made.

RESULTS AND DISCUSSION

Scales suitable for analysis were obtained from 91 of 190 grass carp in six ponds. No samples were obtained from an additional 43 specimens in the seventh pond. At capture, fish were 630–1025 mm TL and 2.80–16.13 kg ($\bar{x}$ = 739 ± 106 mm, 6.5 ± 2.4 kg.). The high proportion of regenerated scales was likely due to scale loss or damage in the hatchery and during handling or

transport. All scales had seven clear annuli. Tissue accumulated beyond the last annulus indicated growth resumption and annulus formation were about to occur at capture.

Annual growth was consistent among ponds, relatively slow during the first two years (81 and 48 mm), increasing dramatically during year 3 (259 mm), and decreasing thereafter (Table 1). Assuming annulus formation in spring, fish were spawned in 1970 and stocked in late (winter) 1971 or early (spring) 1972, prior to second annulus formation. Hatchery growth was poor due to density dependent (Shelton *et al.* 1981) or other factors, a pattern also observed in hatchery fish later collected in the Missouri River (Pflieger 1978). Second annulus formation occurred after stocking. Third year growth was rapid as habitat provided ample space and food. An apparent reduction in annual increment the second year after stocking (fourth year of growth) may reflect reduction in aquatic vegetation, which reportedly was decimated by the grass carp.

Many authors have failed to report or did not know age or lengths of captured grass carp. Few comparable growth data are thus available. Our fish averaged 81 mm at the first annulus. Grass carp attained mean total lengths of 280 mm in a year in Arkansas (Stevenson 1965), and Hora and Pillay (1962) reported lengths of 150 to 300 and 600 mm after one and two years, respectively, in the South Pacific. These rates are considerably greater than ours, which is attributed to slow hatchery growth. Shelton *et al.* (1981) determined first year lengths of 50 to 75 and 175 to 200 mm for grass carp in ponds at densities of 470,000 and 14,000/ha, respectively. Nikol'skii (1954) reported annual growth of grass carp, presumably in nature, as follows: I (77 mm), II (156 mm), III (223 mm), IV (289 mm), V (360 mm), VI (422 mm), and VII (480 mm), lengths similar to those of our fish during the two hatchery years, but considerably less than in subsequent (Arizona) years.

Mean length, weight, and standing crop (kg/ha) of grass carp were similar in five ponds, but all were significantly greater in a sixth (t-test, $p < 0.05$). There appeared a relationship among these parameters, sequential position of ponds within the interconnected system, water quality, and nature of inputs, as postulated by Marsh and Minckley (1983*b*). However, lack of data prevent further quantification except for a linear increase in mean size of fish with increasing standing stock.

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TABLE 1. Density (Number and Biomass per Hectare), Aged Specimen Data, and Back-calculated TL at Consecutive Annuli for Grass Carp from Six Ponds at Sun Lakes, Central Arizona.

						Mean calculated TL (mm ± SD) at annuli						
Pond	Number/ ha	kg/ ha	Number of fish aged	Mean TL at capture ± SD	Mean kg at capture ± SD	1	2	3	4	5	6	7
3	71	289	27	716 ± 40	4.1 ± 0.6	84 ± 20	129 ± 24	349 ± 62	437 ± 49	514 ± 56	601 ± 59	674 ± 53
4	67	330	9	718 ± 47	4.9 ± 1.1	79 ± 14	128 ± 21	371 ± 136	495 ± 94	578 ± 77	655 ± 63	701 ± 52
5	53	583	18	931 ± 49	11.1 ± 2.7	83 ± 18	139 ± 22	509 ± 68	628 ± 66	719 ± 65	804 ± 58	874 ± 57
6	59	224	11	688 ± 33	3.8 ± 0.5	79 ± 16	123 ± 17	356 ± 57	464 ± 67	557 ± 53	611 ± 54	658 ± 36
7	26	95	17	680 ± 19	3.6 ± 0.5	74 ± 18	121 ± 15	353 ± 106	476 ± 54	560 ± 43	625 ± 30	654 ± 22
8	40	108	9	626 ± 25	2.7 ± 0.4	87 ± 21	130 ± 17	379 ± 43	454 ± 16	515 ± 18	575 ± 27	594 ± 26
Combined			91	739 ± 106	6.5 ± 2.4	81 ± 18	129 ± 21	387 ± 100	493 ± 91	574 ± 94	650 ± 94	703 ± 100
Annual Increment (mm)						81	48	259	105	82	76	53

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ORIENTATION OF JUVENILE CHINOOK SALMON, *ONCORHYNCHUS TSHAWYTSCHA,* AND BLUEGILL, *LEPOMIS MACROCHIRUS,* TO LOW WATER VELOCITIES UNDER HIGH AND LOW LIGHT LEVELS

The nocturnal seaward migration of juvenile salmonids has been hypothesized to be the result of a loss of visual and contact stimuli at night which "reduces the intensity of the rheotactic response and results in downstream movement" (Hoar 1951: pg 241). If this is true, it would be expected that juvenile chinook salmon would exhibit a differential ability to detect and orient to low water velocities when tested under light and dark conditions. To test this hypothesis, a series of experiments was conducted to determine the influence of light intensity on the orientation response of juvenile chinook salmon, *Oncorhynchus tshawytscha,* to low water velocities.

The orientation response of juvenile bluegill sunfish, *Lepomis macrochirus,* was also determined for comparison with the orientation response of juvenile chinook salmon. Bluegill were chosen for comparison since they are so ecologically different in their habitat preferences and, presumably, their behavioral response to low-velocity water currents.

METHODS

Juvenile chinook salmon were collected by beach seine from the Sacramento River near Red Bluff, California. Juvenile bluegill were collected by beach seine from Clear Lake, Lake County, California. Prior to testing, all fish were held a minimum of 1 week in a 500-liter fiberglass tank maintained at 15.0 ± 0.5°C. Fish were regularly fed brine shrimp.

Orientation was observed in an experimental system having a test section 123 cm long × 39 cm wide × 27 cm deep. Fish were constrained by plastic screens at both ends of the test section. A horizontal flow of constant velocity ranging from 0 to 2.5 cm/sec could be maintained in the test section by a centrifugal pump and control valves. To minimize turbulence, water flowed from a perforated inflow pipe into a 91-cm transition zone before flowing into the test section. Velocities were determined by measuring dye transit time.

The testing system, open to the sky, was oriented north-south out-of-doors to permit diel variations in naturally occurring light intensity. Black plastic 1.5 m

high surrounded the testing system to exclude extraneous light and movements of the experimenter from the view of the test fish.

Light intensity was measured with a digital photometer (Gamma Scientific Model 820 A) equipped with a footcandle detector head (Model 820-30) and filter having a spectral response from 380-780 nm. Water temperature was measured with a YSI Model 44TD Tele-Thermometer. Water temperature was held approximately constant (15 to 17°C) during testing.

Five fish were placed in the test section 2 hours before the water pump was turned on, and a velocity was randomly selected. The fish were given an additional 30 min to acclimate, after which 10 photographs were taken at 5-min intervals with a camera mounted 325 cm above the testing system. The camera was supported by metal rods extending from the laboratory roof, allowing the experimenter to operate the camera without disturbing the fish.

One set of experiments was conducted from 0900 to 1100 h at a light intensity of 1×10^3 footcandles. For this set, Kodak Tri-X film was used. The experimental system was uniformly lit by the sun, eliminating bias due to selectivity for partially shaded areas of the test sections.

The second set of experiments was conducted from 2200 to 2400 h at a light intensity of 1×10^{-4} footcandles. Photographs were made with Kodak High-Speed Infrared film and an electronic flash equipped with a Kodak No. 88A Written filter which eliminated light in the spectral region less than 740 nm. This photographic system permitted high-resolution recording of fish orientation at night.

The photographs were used to measure the angular orientation of each fish with respect to the direction of water flow. Thus, 0 degree angular orientation would denote a fish orienting directly into the flow (positive orientation) and 180 degrees would denote negative orientation. Angular orientation of fish in static tests was measured with respect to a longitudinal reference line. Angular orientation of each fish from 1 photograph selected at random from the series of 10 taken for each experiment was used in the statistical analysis. This procedure eliminated subjective decisions in quantifying the orientation response.

RESULTS AND DISCUSSION

Angular orientation data from 140 chinook salmon ($\overline{X}$ length 41.1 mm, S.D. 3.1) and 140 bluegill ($\overline{X}$ length 64.2 mm, S.D. 8.0) tested under high (1×10^3 footcandles) and low ($<1 \times 10^{-4}$ footcandles) light levels were analyzed by linear regression analysis. A logarithmic transformation was used because the variance in angular orientation decreased with increasing velocity. In all cases, the regression slope (Figure 1) was significantly different from zero ($P<0.01$). Thus, we conclude that chinook salmon and bluegill are capable of detecting and responding (positive orientation) to constant velocities less than 2.5 cm/sec under both light and dark conditions.

Regression slopes for chinook salmon orientation for light (slope = −0.30) and dark (slope = −0.33) tests were not significantly different ($P>0.05$). Regression slopes for bluegill orientation, −0.25 and −0.27 in light and dark tests, were not significantly different ($P>0.05$). These results indicate that the detection and orientation response of chinook salmon and bluegill was independent of light intensity. Furthermore diferences in regression slopes were not

significant ($P > 0.05$) between salmon and bluegill in light and dark tests, although the two species have very different habitat preferences.

Blinded fish have been used by several other investigators in studies of locomotor behavior and orientation. Although this approach assures the absence of a visual response, we observed high mortality (> 50%) in fish blinded by surgical removal of both eyeballs. With these levels of mortality and accompanying physiological stress, we chose to use unaltered fish tested under natural nighttime light intensities. By using infrared photographic techniques, the fish were tested under conditions typical of natural light levels encountered in shallow streams and lakes on clear, moonless nights. Although our studies do not

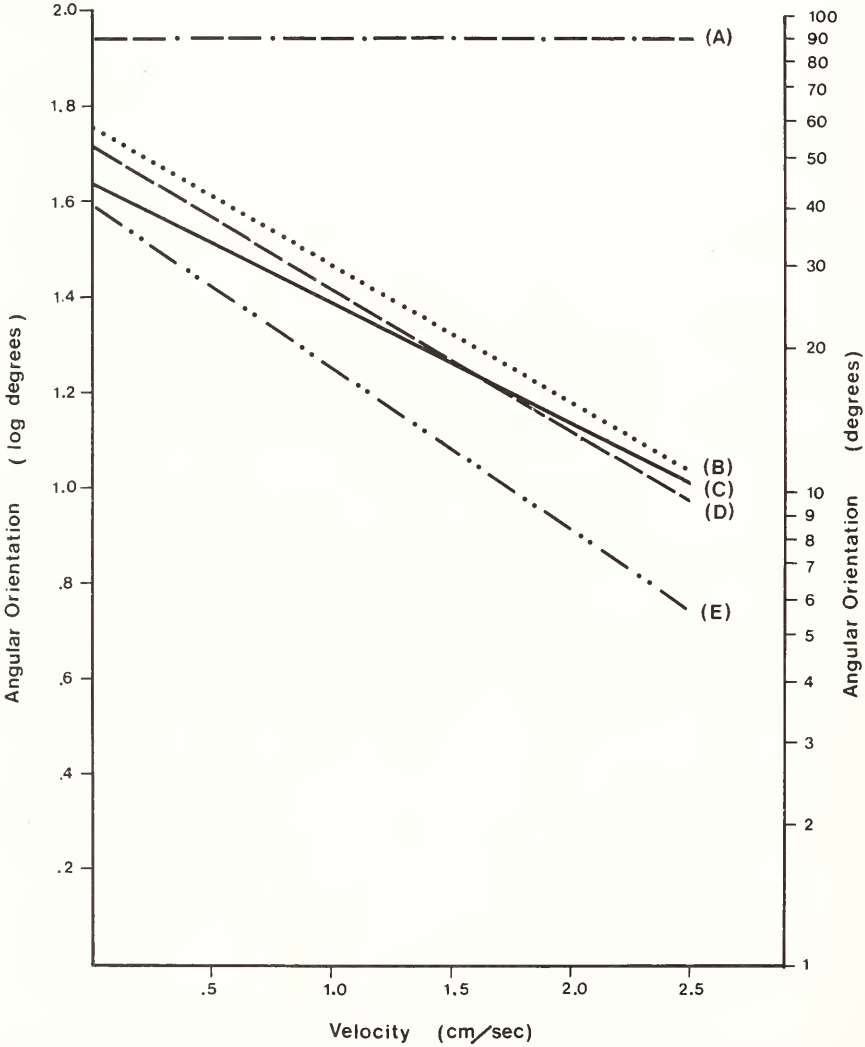

FIGURE 1. Least-squares linear regression of orientation against water velocity: (A) hypothetical line of no response; (B) chinook salmon high light; (C) bluegill low light; (D) bluegill high light; (E) chinook low light.

represent the orientation response of fish in the complete absence of possible visual response, they do reflect conditions encountered under natural diel light regimes.

The ability of juvenile chinook salmon and bluegill to detect and respond to low velocity water currents independently of light intensity suggests that for these species visual cues do not play a significant role in orientation to water currents. Results of this study provide no evidence that the nocturnal seaward migration observed for juvenile salmonids is the result of a loss of the ability to detect and respond to water currents at night.

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RADIO-TAGGED HARBOR SEAL, *PHOCA VITULINA RICHARDSI*, EATEN BY WHITE SHARK, *CARCHARODON CARCHARIAS*, IN THE SOUTHERN CALIFORNIA BIGHT

On 22 July 1983 a commercial fishing vessel caught a male white shark, *Carcharodon carcharias*, in a gill net approximately 16 km south of Anacapa Island, California (lat. 34°00′N., long. 119°25′W). Sea World, Inc., San Diego, obtained the shark and packed it in ice until it was necropsied on 26 July. The shark weighed 948 kg and measured 4.7 m in total length (4.3 m fork length).

The shark's stomach contained the remains of a juvenile elephant seal, *Mirounga angustirostris*, an adult harbor seal, *Phoca vitulina richardsi* [Shaughnessy and Fay (1977) discuss the spelling of the subspecific name of this taxon], a radio-transmitter, and a red Dalton Roto tag. The seals were apparently consumed in large pieces. The head of each was severed cleanly from the torso through the neck, the harbor seal at the third cervical vertebra and the elephant seal behind the occipital condyles. The heads and other tissues were in very early stages of digestion and were likely consumed within several days of the shark's capture. The quantity of tissue and bones in the shark's stomach indicates that most, if not all, of each seal was eaten.

The radio-transmitter (still functioning when tested on 6 August) and the Roto tag had been attached by us to the rear ankle and flipper of an adult female harbor seal (standard length—1.48 m, girth—1.11 m) at San Nicolas Island (lat.

33°15′N, long. 119°30′W) on 23 May 1983. The seal had been hauled out on 18 of 31 days from 6 June through 6 July for an average of 8.0 h per day. If the seal had been hauled out at San Nicolas Island between 7 July and 22 July, the event(s) would have been recorded by one of our Esterline Angus (20 channel, scanning, D.C. powered) recording stations which operated continuously from late March 1983 through August 1983. The seal therefore apparently departed San Nicolas Island on 6 July.

Our preliminary studies of post-breeding and molting season movements of harbor seals in the Southern California Bight suggest that some seals may be pelagic or somewhat migratory in autumn and winter (Stewart 1981, Stewart and Yochem, unpubl. data). We suspect that the radio-tagged seal departed San Nicolas Island after completing the molt in early July and was consumed between 18 and 20 July near the northern Channel Islands.

Evidence for shark predation on pinnipeds consists primarily of observations of shark-like scars and fresh wounds on seals and sea lions, and of remains of harbor seals (Bonham 1942; Fitch 1949; McCosker 1981; LeBoeuf, Riedman and Keys 1982), sea lions (Jordan and Evermann 1896, Walford 1935, Scholl 1983) and elephant seals (McCosker 1981, LeBoeuf *et al.* 1982) found in sharks' stomachs.

Recently, Ainley *et al.* (1981) and Ainley *et al.* (In press) reported 90 independent observations of pinnipeds at the Farallon Islands being attacked and consumed by white sharks from 1970 through 1982. LeBoeuf *et al.* (1982) reported that the stomachs of seven white sharks caught or washed ashore in central and southern California (1975–1978) contained either harbor seal or elephant seal remains. Elephant seals apparently are consumed more frequently by white sharks than are other pinnipeds that occur off California (Ainley *et al.* 1981, LeBoeuf *et al.* 1982, Ainley *et al.* In press).

Attacks by white sharks on pinnipeds (Ainley *et al.* 1981, LeBoeuf *et al.* 1982, Ainley *et al.* In press), sea otters (Ames and Morejohn 1980), and humans (Miller and Collier 1981, Lea and Miller 1983) in coastal California waters have increased in recent years. In northern and central California the increase in number of shark attacks, and possibly in white sharks (Miller and Collier 1981) may be related to an increase in marine mammal populations (Ainley *et al.* 1981, LeBoeuf *et al.* 1982). Populations of northern elephant seals, California sea lions, *Zalophus californianus*, northern fur seals, *Callorhinus ursinus*, and harbor seals have increased significantly during the past fifty years on the Southern California Channel Islands (LeBoeuf and Bonnell 1980; DeLong 1982; DeMaster *et al.* 1982; Cooper and Stewart 1983; Stewart and Yochem 1984). No data are available on the status or growth of the white shark population in the Southern California Bight. From 1979 through 1983 we have observed 48 elephant seals, 11 harbor seals and eight California sea lions at San Nicolas and San Miguel Islands that bore fresh wounds or scars probably inflicted by white sharks. These pinnipeds are seasonally migratory and it is possible that some were attacked north of Point Conception, where white shark attacks have been most obvious (e.g., Ames and Morejohn 1980, Ainley *et al.* 1981, Miller and Collier 1981).

Ainley *et al.* (1981) suggested that "white shark predation is probably an important natural control on pinniped population size." Inasmuch as the pinniped populations in California and Baja California waters are rapidly increasing we see no evidence that shark predation is now an important check to population growth at most rookeries.

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ADDITIONAL RECORDS OF *PRONOTOGRAMMUS MULTIFASCIATUS* AND *GEMPYLUS SERPENS* FROM CALIFORNIA

In the winters of 1979 and 1981 two threadfin bass, *Pronotogrammus multifasciatus* (Family Serranidae), were collected off southern California. *P. multifasciatus* Gill, a senior synonym of *Anthias gordensis* Wade (Fitch 1982), is known from only two California records. Hobson (1975) reported the first California specimen. Fitch (1982) reported *P. multifasciatus* to range as far north as Portuguese Bend, Los Angeles County, California. While Fitch did not list materials examined, it is believed the Portuguese Bend specimen refers to the *P. multifasciatus* (CMM 81.22.2) discussed below. In the spring of 1981 a snake mackerel, *Gempylus serpens* (Family Gempylidae), was collected from southern California. The snake mackerel has been reported from California only once. Both species normally have more southern distributions.

A threadfin bass was trawled from a depth of 72–80 m by Freire Lopez on 19 February 1979. This 110 mm SL specimen was collected by a squid trawler off the California coastline between lat 33°15′-16′ N and long 117°31′-34′ W; the trawl hit bottom during the tow. The specimen was identified by Richard H. Rosenblatt and deposited at Scripps Institution of Oceanography (this specimen was not examined by us).

Another threadfin bass was caught by Joe Crozer on 18 January 1981 in 80 m off Pt. Fermin (lat 33° 42′ N, long 118° 20′ W). This specimen measured 182 mm SL and fits the diagnosis given by Fitch (1982). Color notes were taken soon after death. Dorsal and lateral trunk brilliant red with dark vertical crosshatching. Chin, ventral trunk, caudal peduncle and fin yellow. Head red with dark spotting. Gold stripes radiate from eye to posterior margin of operculum. Color in alcohol tan with pale yellow venter. Eye stripes faint. Gut contents were almost entirely copepods as was noted for the first California specimen (Hobson 1975). It is interesting to note, however, that this specimen was caught on rod-and-reel using an anchovy for bait and was brought to the surface along with "rockcod" (*Sebastes* spp.). The specimen is deposited in the Cabrillo Marine Museum, CMM 81.22.2.

A second California specimen of the snake mackerel was collected at the junction of Cabrillo Beach and the tidepools off Pt. Fermin (lat 33° 42′ N, long 118° 17′ W) by Dennis Crupi and Elizabeth Kelly on 8 March 1981 as it floundered in the surf. The 532 mm SL, 193 g, specimen was easily identified by the long snake-like body, two lateral lines joined anteriorly, and numerous posterior finlets (Fitch and Lavenberg 1968). The specimen is deposited in the Cabrillo Marine Museum, CMM 81.22.1. The first record of *G. serpens* for California was reported by Fitch and Lavenberg (1968). John E. Fitch supplied us with additional information on the fish, LACM 9608-1; the specimen measured 515 mm SL, 535 mm TL, and weighed 170 g. It was collected by Bill Schaefer in a tidepool at Whites Pt., Los Angeles County, on 13 February 1967, as it too swam feebly in shallow water.

There is some evidence that the northward occurrence of these fishes may be correlated to warmer than usual water temperatures. This phenomenon has been documented several times for the California coastlines (Hubbs and Schultz

1929, Walford 1931, Hubbs 1948, Radovich 1961). Mearns (1980) noted that a warm, clear, winter water trend spanned the 1976–80 time period (Mearns, pers. commun., gave us additional temperature data for the April 1980–April 81 period). While these data indicate that 1980 was not a warm water year overall, the fall and winter months of 1980–81 appeared warmer than usual. It should be noted that while *G. serpens* has a normal vertical distribution from the surface to at least 1000 m (Miller and Lea 1976), *P. multifasciatus* tends to stay in cool subsurface waters from 40-205 m (Fitch 1982).

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We gratefully acknowledge the initial efforts of the collectors. B. Wheeler of Seal Beach donated the *P multifasciatus,* CMM 81.22.2.

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PUGHEADEDNESS IN THE CALIFORNIA ROACH *HESPEROLEUCUS SYMMETRICUS* (BAIRD AND GIRARD)

The morphological anomaly known as pugheadedness has been described in at least 14 different families of fish (Table 1). Pugheadedness may be characterized in part, as an abnormal elevation and protrusion of the median portion of the cranium. However, the form and extent of pugheadedness may vary considerably within and between species. Descriptions of skull deformities attributed to pugheadedness in various fishes are presented in Gudger (1930) and Dawson (1964, 1966).

TABLE 1. Published Records of Pugheadedness in Various Families of Fish

SPECIES	*REFERENCE*
Clupeidae	
American shad, *Alosa sapidissima*	Cheek 1965
Menhaden, *Brevoortia tyrannus*	Schwartz 1965
Salmonidae	
Rainbow trout, *Salmo gairdnerii*	Croker 1931
Brown trout, *Salmo trutta*	Forsyth 1926, Gudger 1929
Kundzha, *Salvelinus leucomaenis*	Honma and Yoshie 1978
Esocidae	
Northern pike, *Esox lucius*	Lawler 1966
Cyprinidae	
Common carp, *Cyprinus carpio*	Rondelet 1555
Verkhovka, *Leucaspius delineatus*	Knauthe 1893*a*, 1893*b*
Percichthyidae	
Striped bass, *Morone saxatilis*	Ayres 1849; Sutton 1913; Mansuetti 1958, 1960; Alperin 1965; Smith 1967; Grinstead 1971
White bass, *Roccus chrysops*	Panceri 1872; Mazza 1893; Fasciolo 1904
Centrarchidae	
Largemouth bass, *Micropterus salmoides*	Herrick 1885
Percidae	
Yellow perch, *Perca flavescens*	Cheek 1965, Lawler 1966
Percid, *Stizostedion* sp.	Pellegrin 1908
Pomatomidae	
Bluefish, *Pomatomus saltatrix*	Hickey and Austin 1974
Lutjanidae	
Vermilion snapper, *Rhomboplites aurorubens*	Bortone 1971
Sciaenidae	
Silver perch, *Bairdiella chrysura*	Gudger 1930
Spotted seatrout, *Cynoscion nebulosus*	Rose and Harris 1968
Labridae	
Tautog, *Tautoga onitis*	Briggs 1966
Zaniolepididae,	
Zaniolepis latipinnis	Talent 1975
Aphredoderidae	
Pirate perch, *Aphredoderus sayanus*	Bortone 1971
Gadidae	
Cod, *Gadus* sp.	Cheek 1965

Two pugheaded California roach, *Hesperoleucus symmetricus*, were recorded from streams in separate drainages as part of collections made during a larger zoogeographic study of stream fishes of the San Francisco Bay drainage basin (Leidy, 1984). Although this deformity has been recorded in two other cyprinid species, these specimens represent the first published record of pugheadedness in the California roach.

On 23 July 1981, a single specimen was collected from San Lorenzo Creek, a small, intermittent, urbanized stream tributary to San Francisco Bay, California (Figure 1). This specimen measured 59 mm fork length (FL) and was taken in a sample of 162 juvenile and adult California roach, ranging from 51 to 101 mm FL. This pugheaded specimen exhibited an elevation of the cranium in the orbital region with what appears to be an oblique elongation of the orbits (Figure 2.) The forehead is steep and there is a protrusion of the mandibles, although the lower jaw is lacking slightly. No exophthalmia was noted.

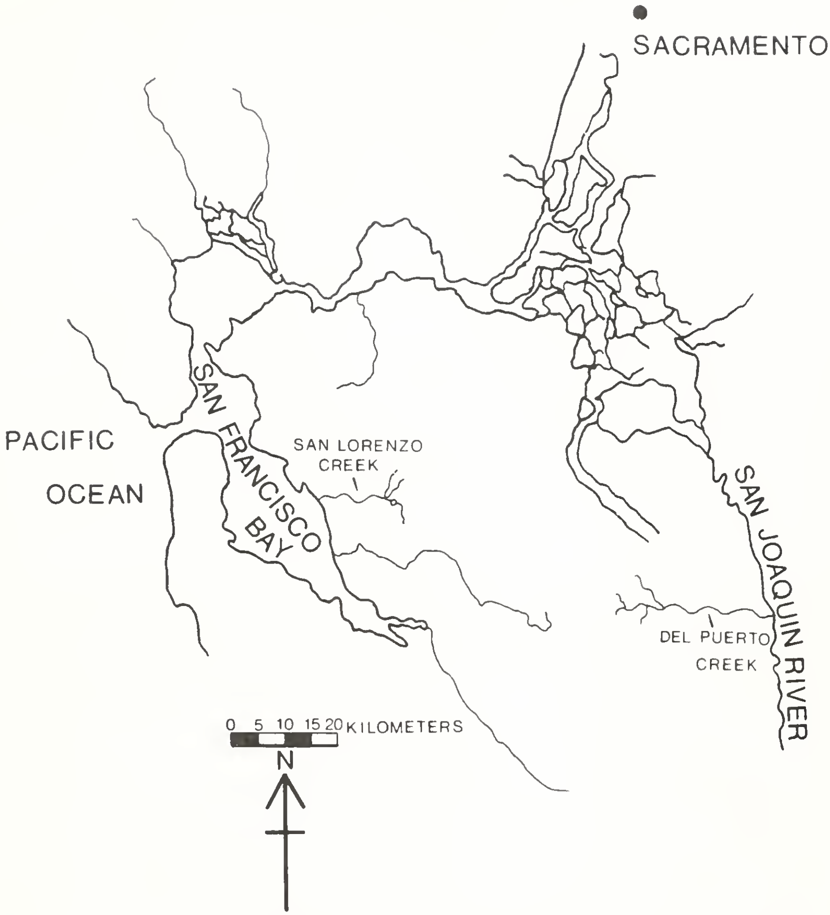

FIGURE 1. Map showing the locations of streams where pugheaded *Hesperoleucus symmetricus* were collected.

On 10 October 1981, a second pugheaded California roach was collected from Del Puerto Creek, an intermittent tributary of the San Joaquin River system, draining the dry, eastern slope of the Inner Coast Ranges (Figure 1). This specimen measured 67 mm FL and was collected in a sample of 10 juvenile and adult California roach, ranging from 37 to 80 mm FL (Figure 3). As was evident in the other pugheaded specimen, the cranium in the region of the eyes had been elevated. The orbit exhibited a slightly enlarged diameter, but no exophthalmia was evident. In contrast to the San Lorenzo Creek roach, this specimen exhibited a blunted snout and protruding lower mandible (Figure 4). The angle created by the intersection of the line of the flattened cranium and the line of the snout approaches 90°. The upper jaw appears to be lacking.

Both specimens exhibited no other external morphological abnormalities, although both non-pugheaded fish and the single pugheaded specimen collected in Del Puerto Creek were heavily parasitized. The belly of each specimen was distended when collected, indicating that the abnormality did not inhibit feeding ability. Both specimens have been retained by the author.

FIGURE 2. A non-pugheaded California roach, *Hesperoleucus symmetricus,* above, and pugheaded specimen from San Lorenzo Creek, below.

FIGURE 3. A non-pugheaded California roach, *Hesperoleucus symmetricus,* above, and a pugheaded specimen from Del Puerto Creek, below.

FIGURE 4. A pugheaded specimen from San Lorenzo Creek, above, and a pugheaded specimen from Del Puerto Creek, below.

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MILKFISH, *CHANOS CHANOS* (FORSSKÅL, 1775), TAKEN IN SOUTHERN CALIFORNIA ADDS NEW FAMILY (CHANIDAE) TO THE CALIFORNIA MARINE FAUNA

Six milkfish, *Chanos chanos,* taken in 1982 and 1983 establish the presence of the family Chanidae in California.

On 22 March 1982 fisherman Luigi San Filippo caught an unusual fish while gill netting for striped mullet, *Mugil cephalus,* with a 3½-inch mesh net, in the warm water discharge plume of a south San Diego Bay power plant (lat 32° 36′ 30″ N, long 117° 06′ 30″ W). One of us (JMD) was contacted and identified the fish as a 925 mm total length (TL), 680 mm standard length (SL), 5.6 kg, milkfish (Figure 1). The specimen is deposited at Scripps Institution of Oceanography, Division of Marine Vertebrates (SIO 82-22).

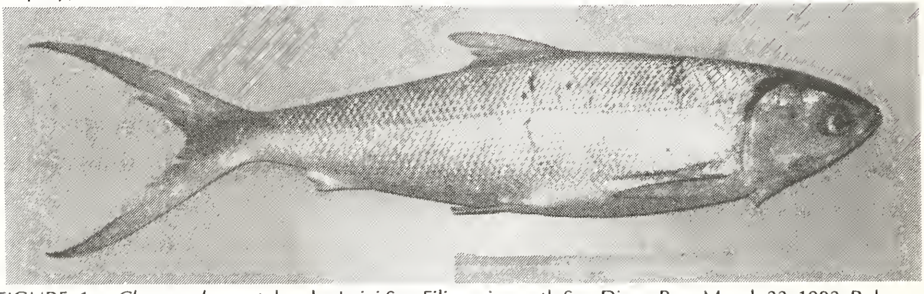

FIGURE 1. *Chanos chanos* taken by Luigi San Filippo in south San Diego Bay, March 22, 1982. Rule is 305 mm. *Photograph by John M. Duffy.*

Two other fishermen caught milkfish off the southern California coast in 1982 and one was taken in 1983. On 7 August 1982 a specimen was taken just outside the San Pedro breakwater (lat 33° 42′ 25″ N, long 118° 15′ 00″ W) by John Guglielmo in a gill net. The late John E. Fitch, California Department of Fish and Game, retired, identified the fish and determined its length to be 970 mm TL, 745

mm SL, and its weight to be 7.3 kg. It is deposited at the Natural History Museum of Los Angeles County (LACM 42887-1).

On 9 August 1982 three more milkfish were taken in the San Diego area. Fisherman Mike Irey caught them in a 6½-inch mesh gill net set in heavy kelp (*Macrocystis* sp.) off Point Loma, near the entrance to San Diego Bay (lat 32° 41′ 00″ N, long 117° 16′ 00″ W). Denyse Racine, California Department of Fish and Game, identified the fish, measuring 1024 mm TL, 1047 mm TL, and 1055 mm TL and weighing 7.9 kg, 9.3 kg, and 8.6 kg, respectively. All three fish were sold for food.

On 30 December 1983 Stephan Hadley snagged a milkfish with an artificial lure, in Quivira Basin, Mission Bay (lat 32° 45′ 45″ N, long 117° 14′ 15″ W). Sportsmen's Seafood Market retained the fish until Hannah Bernard and Bob Read, California Department of Fish and Game, identified the specimen as a 1010 mm TL, 765 mm SL, 7 kg, milkfish. Richard Rosenblatt, SIO, examined the fish and determined that it was a mature female with inactive oocytes. The fish is deposited at SIO (SIO 83-177).

Schuster (1960) reported the world wide range of *C. chanos* to include the tropic and subtropic sections of the Indian and Pacific Oceans, 30° to 40° N to 30° to 40° S lat and 40° E to 100° W long. Neither Miller and Lea (1972) nor Hubbs, Follett, and Dempster (1979) included its range along the California coast. Fowler (1938) added the Galapagos Islands and Chirichigno (1978) the coast of Peru for recent uncommon records of *C. chanos;* yet the milkfish is not uncommon in the Gulf of California from Guaymas to Mazatlan (Evermann and Jenkins 1981, Jordan 1895, Thomson and McKibbin 1976). Migdalski and Fichter (1976) suggest the possible presence of *C. chanos* along the coast of "lower California," which we infer from historical usage to mean Baja California, Mexico. Eschmeyer, Herald, and Hammann (1983, p. 63) note that the milkfish "occasionally strays to S. Calif."; this information was provided by the late John E. Fitch (William N. Eschmeyer, California Academy of Sciences, pers. commun.).

In 1877, 100 milkfish were brought to California from Hawaii in exchange for salmon and trout eggs (Calif. Comm. of Fisheries 1877). The fish were introduced in a small stream at Bridgeport, Solano County. There is no record of their survival.

There have been, however, three reports of the milkfishes' appearance along the coast of Baja and southern California during the last 55 years. Clark (1929) reported a specimen in a San Pedro fish market that had been taken "off the western coast of Lower California." A milkfish was observed floating dead in south San Diego Bay, also in 1929 (John E. Fitch, pers. commun.). Not until May 1979 was another specimen noted. San Diego fisherman Ed Simpson caught a milkfish on hook-and-line in south San Diego Bay, near where San Filippo's fish was taken. Richard Rosenblatt, SIO, identified the specimen as a milkfish from the remains of the caudal peduncle and caudal fin which are deposited at SIO (SIO 79-345).

The 1982 specimen from off San Pedro represents a northern range extension of approximately 1786 km from an area off the west coast of Mexico between Mazatlan and Guaymas (Figure 2). We believe that this locale is the most likely source for these fish. Our specimens were all large and presumably adult fish (maximum reported size 1.7 m—in Nelson 1976) which would easily be able to make the journey to our coastline.

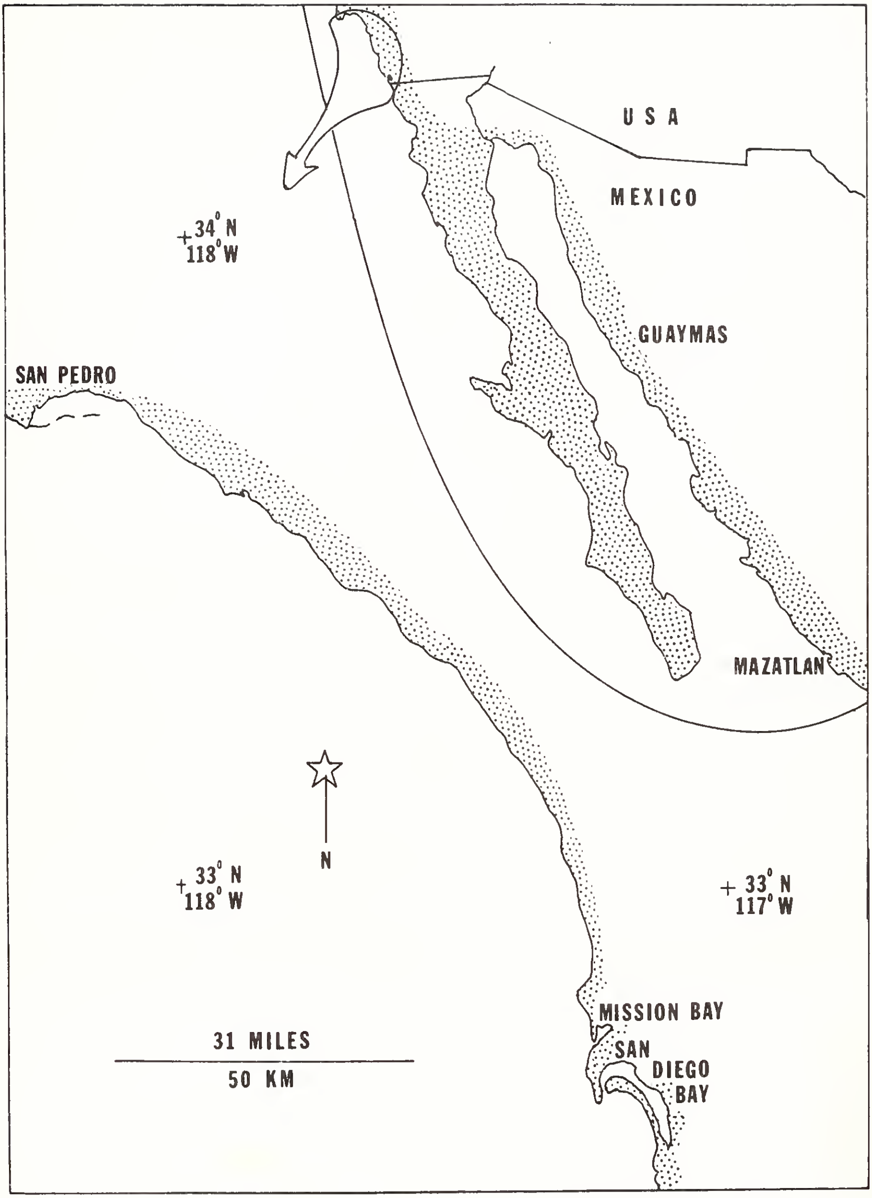

FIGURE 2. *Chanos chanos* catch locations in southern California. Inset is not to scale.

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R. H. Rosenblatt, SIO, and C. C. Swift and R. J. Lavenberg, LACM, allowed us access to their respective fish collections and provided assistance.

California Department of Fish and Game employees assisted us in many ways. D. Racine provided the information on Irey's fish. R. Read assisted in examining

Hadley's fish. R. N. Lea and H. W. Frey both provided references, reviewed the manuscript, and provided helpful comments. G. Quiros checked all literature citations. The late J. E. Fitch provided measurements of the San Pedro specimen and references, observations, and encouragement unobtainable from any other source. D. Gittings, National Marine Fisheries Service and P. Leverenz, SIO, provided assistance in obtaining references.

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EXPERIMENTAL LEAD DOSING OF NORTHERN PINTAILS IN CALIFORNIA

As a result of the decision by the U.S. Fish and Wildlife Service (FWS) to implement steel shot regulations in selected areas of the Pacific Flyway (FWS 1976) the California Department of Fish and Game (DFG), in cooperation with FWS began intensive investigations into waterfowl lead poisoning in 1974. A dosing study was considered a possible means of indirectly measuring mortality from ingested lead. By examining band recovery rates of birds shot in years after banding, it should be possible to measure differences in survival between dosed and undosed birds. This experiment assumes an equal probability that dosed and undosed birds will be recovered, given that they survive to the beginning of the hunting season following banding. The study was designed by DFG in cooperation with FWS, which also provided funds.

The northern pintail was chosen as the species to test because it is the most abundant wintering duck in California, is highly sought after by hunters, is known to ingest lead, and can be trapped in large enough numbers to be meaningful. The original goal was to trap 15,000 birds after the close of the hunting season and dose half of these with lead shot.

METHODS

Pintail were trapped in 7 areas of the Central Valley, from Mendota Wildlife Area, Fresno County, in the south, to Sacramento National Wildlife Refuge, Glenn County, in the north, and at Lower Klamath National Wildlife Refuge, Siskiyou County, in the Klamath Basin. Trapping took place from 22 January 1979 to 23 March 1979. Standard swim-in funnel traps baited with barley were used at all trap sites.

As each bird was removed from the trap it was sexed and banded, after which a plexiglass tube was inserted into the esophagus as far as the crop. Two No. 5 lead pellets were placed in the tube in every other duck of each sex. This dosage was chosen as best approximating i) the average amount of lead found in pintail gizzards examined during studies of ingestion rates in California, and ii) the dosage used by Bellrose (1959) in his work on Illinois mallards. Birds were released immediately after dosing. Tubes were dipped in an antiseptic solution between each usage to prevent the potential spread of disease.

In an effort to increase hunter reporting rates (George Jonkel, Bird Banding Laboratory, USFWS, pers. commun.) red, anodized, aluminum bands were used in this study. In addition, a press release was issued and sportsmen's groups were contacted in person to describe the purpose of the project.

RESULTS AND DISCUSSION

Trapping yielded 12,263 birds, of which 6,109 were dosed and 6,154 served as controls. The unequal number of banded birds in the two groups at a particular banding station (Table 1) was due to the tendency of crews to begin banding each day, or at each trap, with the same treatment regardless of the treatment last used at the previous trap. As of May 1, 1984, 854 recoveries had been obtained (Table 1).

Only recoveries from birds shot or found dead during the hunting season were used for analysis of recovery rates. The overall recovery rate, males and females combined, through the first hunting season after banding was 2.8%. Average recovery rate through the first hunting season for pintail banded at Gray Lodge Wildlife Area (1974–1978) was 3.1%. The difference is insignificant ($x^2 = 0.61, P < 0.005$). Birds retrapped during the preseason banding period of 1979 had already lost much of the red coloring from their bands. It is possible that hunters just didn't notice the different nature of the anodized bands, or that return rates may actually have been negatively influenced by the publicity about the study. Some hunters may have felt they would be contributing to a steel shot requirement if they participated. In any case, the attempts to increase reporting rates were not successful.

The central question of this study is whether lead dosage resulted in decreased survival probabilities of winter-banded pintails. The recovery rate of a group of pintails can be thought of as the product of survival probability and recovery probability. Since there is no reason to reject the assumption of equal probability of recovery between dosed and control groups, recovery rates can be used as a measure of the probabilities of survival.

Chi square tests showed insignificant differences ($P < 0.05$) in recovery rates among banding sites for each sex-treatment group, permitting pooling of the samples. A one-tailed test for the difference in recovery rates between dosed and control birds was then computed for males and females, respectively. The results

TABLE 1. Recoveries of Pintail Banded in California Postseason 1979

	Control Birds						*Lead Dosed Birds*					
	Males			*Females*			*Males*			*Females*		
Banding Site (lat.-long.)	*Number banded*	*Number recovered*	*Recovery rate*	*Number banded*	*Number recovered*	*Recovery rate*	*Number banded*	*Number recovered*	*Recovery rate*	*Number banded*	*Number recovered*	*Recovery rate*
Mendota WA (364-1202)	932	79	0.0847	324	10	0.0309	930	80	0.0860	328	15	0.0457
South Grasslands (365-1204)	759	61	0.0803	282	9	0.0319	759	70	0.0922	280	5	0.0178
Merced NWR (370-1203)	21	1	0.0476	16	1	0.0625	21	2	0.0952	17	1	0.0588
Yolo Bypass (383-1213)	562	40	0.0711	172	3	0.0174	558	50	0.0896	162	6	0.0370
Gray Lodge WA (391-1214)	1334	122	0.0914	582	20	0.0343	1354	108	0.0797	599	19	0.0317
Delevan/Colusa NWR (391-1220)	783	53	0.0676	253	12	0.0474	712	56	0.0786	253	9	0.0355
Sacramento NWR (393-1221)	22	1	0.0455	15	0	0.0000	26	2	0.0769	11	1	0.0909
Lower Klamath NWR (415-1219)	57	5	0.0877	40	2	0.0500	58	9	0.1552	41	2	0.0488
Totals	4470	362	0.0809	1684	57	0.0338	4418	377	0.0853	1691	58	0.0343
All control	6154	419	0.0680			Total males banded - 8888						
All dosed	6109	435	0.0712			Total females banded -3375						

(z=0.74, P=0.77 for males and 0.034, 0.53 for females) show no statistical differences in recovery rates between dosed and control birds of either sex.

Because of the insignificance of the statistical tests, it is desirable to assess the power of the tests, which can be defined as the probability of detecting a difference in recovery rates when a true difference exists. These probabilities were computed for differences of 5 to 20% for both sexes (Table 2). There was a 4 out of 5 chance of detecting a 15% difference in recovery rates between dosed and control males, but only a 44% chance of detecting as much as a 20% difference in females. We then examined the adequacy of our sample sizes. To provide an 80% chance of detecting a 15% difference in recovery rates in males, the banded sample (8,888) was adequate (Table 3), but for females the sample (3,375) was less than half that needed to detect a 20% difference.

TABLE 2. Probabilities of Detecting Specified Differences in Recovery Rates at cx = 0.1 with Present Sample Size

Dosed recovery rate/control recovery rate	*male*	*female*
0.95	0.28	0.15
0.90	0.44	0.23
0.85	0.81	0.33
0.80	0.95	0.44

TABLE 3. Sample Size Needed for an 80% Chance of Detecting Specified Differences in Recovery Rates at cx = 0.1

Dosed recovery rate/control recovery rate	*male*	*female*
0.95	54,848	137,779
0.90	13,383	33,573
0.85	5,798	14,527
0.80	3;176	7,946

Bellrose (1959) reported that male mallards of all ages dosed with 2 No. 6 shot suffered an average of 23% greater mortality than controls, but for adult birds, the figure was closer to 44%. If the dosed pintails in the present study were affected to the same degree, this magnitude of mortality should have been detected with the recovery rates and banded sample sizes of males we experienced. This did not occur. Samples of females are smaller, but this study suggests that California pintails dosed with lead in the late winter and spring did not experience major mortality from such dosing. It also indicates the inadvisability of applying the results of a dosing study on one species to broad geographical areas and to other species.

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